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## Sociotechnical system analysis of weeding, key step for designing agro-ecological systems at the watershed scale

Pauline Della Rossa, Charles Mottes, Marianne Le Bail, Philippe Cattan,  
Magalie Jannoyer

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# Tropentag 2017

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

## **Future Agriculture: Socio-ecological transitions and bio-cultural shifts**

Book of abstracts

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# Preface

*Tropentag* is an annual international conference on food security, natural resource management and rural development. *Tropentag 2017* is organised by the University of Bonn, Germany, 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 Conference theme is "Future Agriculture: social-ecological transitions and bio-cultural shifts".

Future agriculture is by definition an emerging phenomenon. It is continuously in the making, while present visions of the future turn into history. Vast stretches of land in developing countries are being put to new uses, with new forms of governance, new ownership patterns and new forms of production. Particularly agricultural systems are undergoing drastic changes, unfolding an enormous transformative power and affecting millions of people.

System-immanent attributes such as visions, aspirations, cultural specifics and production factor availability shape the response of land users to growing external pressures such as climate change, market demands, land degradation, emerging diseases and policies. In addition to such social-ecological transitions, substantial bio-cultural shifts occur and are imposed by centrally-planned establishments of large-scale intensification (or conservation) corridors and protection zones, or are associated with infrastructure development and urbanisation processes. A wide array of resulting response pathways and land use or production strategies emerge that may be beneficial for rural and urban populations, but can also lead to abandonment of land, migration and conflicts.

Three dominant land-use types are emerging, comprising the diversification or specialisation in low-input small-holder systems, the intensification of agricultural production on large and medium-sized farms, and conservation of natural resources in national parks, community-managed conservancies and game reserves. The three processes are sometimes competing and overlapping with each other, thereby creating regionally diverse configurations of land-use patterns.

1. Generating income or sustaining livelihood from small land holdings and often under conditions of poor resource base quality increasingly involves a shift towards diversification or in specialisation to high-value niche products. Such

strategies are strongly linked to and benefit from the emergence of and access to markets or the willingness of consumers to pay premium prices for specialty products. Diversification is exemplified by (certified) organic production systems. Specialisation may involve the production of spices / medicinal plants or of sticky pigmented rice. While requiring only small land holdings to ensure livelihood of the household, such strategies tend to be labour- and/or knowledge-intensive, entailing production risks through high dependencies on specific markets and value chains, and often requiring new forms of social organisation.

2. Spaces of irrigated food production and of agro-industrial products for export are mostly concentrated in high-potential areas with favourable resource bases, resulting in the establishment of capital-intensive agro-hubs with far-reaching consequences for local livelihoods. Agricultural intensification is often instigated by massive capital flows guided by international agreements and global value-chain development, but also responding to transformative processes at national and regional scales such as growth of urban centres, the rise of a new middle class with new patterns of consumption, and the introduction of modern technologies.
3. Conservation seems to take the opposite direction, because agricultural and pastoral forms of land use are marginalized or even excluded from the conservation areas. Over the past years, parks and protection zones have mushroomed, implemented under the guidance of international organizations and programs. In addition, private land owners and local communities are establishing smaller community-managed conservancies. Zones of conservation are not only seen as attractions for tourists, but may act as carbon sinks and a response to climate change or biodiversity loss.

At a first glance, it may seem as if these three avenues of land-use change are heading in opposite directions. However, they all respond to global regulatory regimes and incentive structures, leading to a transformation of nature and social ecologies. As a consequence, such avenues of land-use change converge in massive transformations of local livelihoods. Some occur gradually over extended periods of time, entailing an ‘evolutionary’ social-ecological transformation. Others are more drastic and implemented rapidly and at large scale, resulting in ‘revolutionary’ biocultural shifts.

What are the implications of such developments and change processes for food security, resource base quality, rural well-being, and in general for ‘future agriculture’, and where are the challenges and research needs? Can intensification strategies with support from engineering, agricultural chemistry and modern breeding meet the ex-

pectations and targets formulated in the sustainable development goals? What are the social and environmental trade-offs? Where and when are small-holder low-input strategies the way forward to reaching the goals? Where are the social-ecological niches for high- and low-input approaches and how can these apparently antagonistic strategies be reconciled for future rural well-being?

These questions and related topics will be addressed in plenary key note lectures and in presentations and poster contributions organised in 24 thematic sessions. Special emphasis in this year will be given to agroforestry systems with contributions of this year's CGIAR feature partner, the World Agroforestry Centre (ICRAF). A 'new' area of Tropentag 2017 is the expansion from the 'classical' tropical and subtropical environments to include land use changes and production challenges in Central Asia.

We hope that the scientific contributions in this book will help you to find answers to the important research and development questions and to the "future agriculture" theme. We wish you an enjoyable and rewarding conference.

The organising committee of *Tropentag 2017*

Mathias Becker

Christian Borgemeister

Kai Behn

Eric Tielkes

Bonn, September 2017



# Message from Federal Minister Müller

Dear Participants of this year's *Tropentag*,  
Hunger is the greatest preventable scandal on our planet - preventable because the earth can produce enough food to feed everyone. We *can* overcome hunger and malnutrition if we want to - *and* if we make it a priority to do so.

By 2050 the world population will probably have grown to 10 billion people. To feed all these people adequately, productivity levels will have to increase by 60 per cent. As a consequence, the agricultural systems in the tropics and the sub-tropics in particular will come under great pressure to adapt. This means that tropical rainforests are under particular threat of conversion to pasture or cropland.

We cannot continue along this path. Rather, we need to find a new model for sustainable agricultural production and rural development. The last great step change in agriculture, sometimes referred to as the "green revolution" was geared very heavily towards increasing production - too often at great cost to biodiversity, soil and forests. What we really need are higher yields achieved by production methods that take into account the limits of our planet. People working in the agricultural sector must become problem solvers and come up with new production methods that conserve our planet's resources and climate. In other words, production methods that are good for both mankind *and* nature.

Germany needs to lead the way. That is why the Federal Ministry for Economic Cooperation and Development launched the ONE WORLD – NO HUNGER initiative in 2014 and has since invested 1.5 billion euros a year in food, agriculture and rural development. Since its launch, the special initiative has developed into a broad-based nationwide alliance, with more than 75 participating members from science and academia, church organisations, civil society and the private sector.

I am pleased that the scientific community is active in this alliance. We need their input, since agricultural innovation will be the driving force behind advances in productivity and resource efficiency. We shall be able to transition to a modern, market-oriented yet resource-sparing agricultural system only if we have access to knowledge, markets, capital and production inputs and can draw on superior organisation and infrastructure.



**“Future Agriculture: Social-ecological transitions and bio-cultural shifts”** is the main topic of the 2017 *Tropentag*, which is being held here in Bonn, the German ‘capital’ of development policy, for the fourth time.

An expected 750 experts from 72 countries will make the *Tropentag* the biggest interdisciplinary conference for development-focused research on tropical and sub-tropical agriculture, resource management and rural development.

I wish you all a successful conference, and look forward to this event producing ideas and outcomes that will point the way forward not only to sustainable agricultural production but also to ways of improving the long-term prospects for rural areas.

Dr. Gerd Müller  
Federal Minister for Economic Cooperation and Development

# Contents

<b>Plenary speeches</b>	<b>11</b>
<b>1. Plants and land use</b>	<b>15</b>
1) Biodiversity and underutilised species	17
2) Land use and land use change	45
3) Crop biotic stresses (DPG Session)	69
4) Biomass, biofuel and bioeconomy	97
<b>2. Plants and soil</b>	<b>117</b>
1) Soil and soil fertility	119
2) Fertilisers	147
3) Production systems	175
4) Crop genetic resources and abiotic stress	199
<b>3. Resources and knowledge</b>	<b>223</b>
1) Water and irrigation	225
2) Modelling	245
3) ICRAF session	267
4) Knowledge systems	291
<b>4. Animals and food</b>	<b>319</b>
1) Animal husbandry	321
2) Animal nutrition	347
3) Agricultural and food technology	381
4) Agrobiodiversity and nutrition diversity	407
<b>5. Economics</b>	<b>431</b>
1) Markets	433
2) Value chains	451
3) Risk and awareness	475
4) Institutions and livelihood	499

<b>6. Institutions</b>	<b>525</b>
1) Central Asia I	527
2) BMEL session	547
3) GIZ session: Scaling Out - Cooperation between Research and Development	557
4) Central Asia II	561
<b>Index of authors</b>	<b>567</b>
<b>Index of keywords</b>	<b>583</b>
<b>Index of abstract IDs</b>	<b>597</b>

# Plenary speeches

---

ANTHONY SIMONS:

**The Future of Agriculture: “Land-Use Change” or  
“Land Changing Uses”?**

**12**

BINA AGARWAL:

**Rethinking the Way We Farm**

**13**

MARTIN KROPFF:

**The Future of Agriculture: Which Way to Go?**

**14**

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## The Future of Agriculture: “Land-Use Change” or “Land Changing Uses”?

ANTHONY SIMONS

*World Agroforestry Centre (ICRAF), Office of the Director General, Kenya*

Throughout history when it comes to feeding humanity we have moved through four main phases. In the first phase, we had 140,000 years of being hunter-gatherers and we got pretty good at it such that we were able to colonise most of the planet. Ten thousand years ago in the second phase we became rudimentary cultivators and in several locations created large enough food surpluses to enable population clusters of non-cultivators to form. Not all cultivators produced surplus though and many just subsisted or perished. The third phase over the past 500 years, albeit happening at different rates in different places, saw agriculture emerge as a major commercial enterprise and both provided livelihoods for rural dwellers as well as fed growing urban populations but this came at a high environmental and habitat use cost. And sadly in the developing world the subsisters and perishers still predominated. The “modernisation of agriculture” being the most recent fourth phase has seen food being produced from a third of all terrestrial land (1.5 billion hectares of arable land and 2.8 billion hectares of rangeland and pastures). This phase includes everything from the Asian Green Revolution, to factory farming to satellite guided machinery, but again disgracefully is augmented by a majority of subsisters. So after 5000 generations of humanity it seems pretty clear that agricultural landscapes are too important to ‘only’ serve the function of food production. Agricultural landscapes must also serve environmental, social and economic functions as laid out in the Sustainable Development Goals (SDGs). Agricultural land needs to broaden its uses rather than changing more land to agriculture – not just for better functioning but also as we are running out of land. This presentation explores how trees - the longest lived lifeforms on Earth can deliver multiple benefits for the SDGs and to secure life on Earth. It sets out an agenda – including for research – on how we might secure these benefits while improving the way agriculture is carried out in both tropical and temperate settings. The presentation sets the ambition for transformation of agriculture and rural land management systems to be sustainable based on improving their productive resilience in an diversified and equitable manner.

## Rethinking the Way We Farm

BINA AGARWAL

*University of Manchester, Development Economics and Environment, United Kingdom*

We stand today at a cross-road. We have a crisis not just of agriculture but of the rural economy itself. Some 80 per cent of farmers in developing countries are small (cultivating 2 hectares or less) and increasingly female, as more men than women move to non-farm jobs. They face challenges in accessing land, other inputs, technology and markets, and live under a growing shadow of climate change on the one hand and inadequate growth of alternative job options on the other. In addition, decades of agricultural intensification and shifts to monocultures have left in their wake depleting soils, falling watertables, and disappearing crop diversity. Clearly we need to rethink the way we farm, not just technologically, but more fundamentally, institutionally. The global debate on food security and the kinds of farming systems that could prove economically and ecologically sustainable has focused overwhelmingly on small family farms versus large commercial farms, with little attention to alternative models based on farmer cooperation. Drawing on examples especially from South Asia, this talk will examine the nature of the agrarian crises and potential alternative pathways.

## The Future of Agriculture: Which Way to Go?

MARTIN KROPFF

*International Maize and Wheat Improvement Center (CIMMYT), Mexico*

The question remains whether we can increase food production by 2050 to meet the demand of growing populations and their changing dietary habits, while also developing economically and adapting to increasing pressure from climate change, depleting natural resources and competition for land.

For many, development is defined by the “demographic transition” from largely rural agrarian societies to a predominantly urban industrial society. That being said, there is still a massive disparity between high economic growth and progress in the fight for food and nutrition security. Agriculture needs to go through a major transformation to bridge this gap — and the good news is that in many ways it already is.

What needs to happen next?

Firstly, we need to shift our thinking from agriculture to agri-food systems and from fields to landscapes. In addition to farmers, consumers, processors and distributors play a pivotal role in the availability, quality, sustainability and safety of food products. Nutritional and food security is not just being driven by what happens on the farm, but by many other factors along the pathway from gene discovery to food on a plate. The key to a food-secure future is how we harmonise and align these different interests, understand trade-offs and work multidisciplinary. Secondly, agriculture must be an exciting and economically viable business to attract and retain new generations. Rural infrastructure and services, business skills, farmer organisations, entrepreneurship and technology are key to making this happen. Addressing youth-specific as well as larger social inclusion issues via policies will be important. What kind of environment does agriculture need now to thrive in 30 years?

Linked to this is the need for a technological revolution in agriculture. Although many technologies are available, we need to move them beyond the research stage to end users. Advances in genomics and remote sensing, to name a few technological innovations, can be used to increase food production and ease pressure on natural resources.

Achieving this agricultural transformation requires a better integration of research domains and sharing research infrastructure and data, to better leverage global expertise and technologies, according to a recent CIMMYT-led article published in the journal *Science*. Creating the next generation of Global Crop Improvement Networks presents a new partnership opportunity for CGIAR and German researchers, development practitioners and policy-makers.

Germany has a long history of investing in *Laendliche Entwicklung*. This could lead the way in encouraging new collaborative paradigms, encompassing a broad range of stakeholders at different stages of the research-to-development cycle, to help build resilient agri-food systems.

# Plants and land use

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1) Biodiversity and underutilised species	17
2) Land use and land use change	45
3) Crop biotic stresses (DPG Session)	69
4) Biomass, biofuel and bioeconomy	97

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# Biodiversity and underutilised species

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## Invited Paper

- ELENA POPOVA, CHARLOTTE E. LUSTY, LUIGI GUARINO:  
**Building a Global System for *ex situ* Conservation of Crop Diversity** 20

## Oral Presentations

- KATHARINA STEIN, KATHRIN STENCHLY, DRISSA COULIBALY, ALAIN PAULY, INGOLF STEFFAN-DEWENTER, SOULEYMANE KONATÉ, DETHARDT GOETZE, STEFAN POREMBSKI, KARL-EDUARD LINSENMIR:  
**Bee Pollinator Communities and Human Disturbance in West African Savannahs – Implications for Crop Yield?** 21

- KAI BEHN, SAMUEL MUTEPI, MIGUEL ALVAREZ:  
**Diversity of East African Wetland Vegetation: A Classification Based on Current and Historic Surveys** 22

- NEEMA MOGHA, COLLINS HANDA, MIGUEL ALVAREZ, BODO MÖSELER, HELLEN KAMIRI:  
**Plant Communities Changes in Relation to Land Uses and Soil Properties in Malinda Wetland, Tanzania** 23

- MIRJAM PULLEMAN, PABLO SILES, EDWIN GARCIA, CARSTEN MAROHN, MELANIE MASON, ORLANDO TELLEZ, ELBIS CHAVARRIA, EMILY WEBSTER:  
**Agroforestry-Based Restoration and Enhanced Resilience of Agricultural Production through Adaptation of Smallholder Farming Systems, Nicaragua** 24

## Posters

- PEDRO DANIEL PARDO VILLEGAS, PATRICIA LANDAVERDE GONZALEZ, SVEN WAGNER:  
**Vegetation-Based Indicators for Assessing Ecosystem Services of Cacao Agroforestry Systems, Buffer Zone of Abiseo River National Park, Peru** 26

- STEFANIE CHRISTMANN, ATHANASIOS TSIVELIKAS, ABDELAH BENBYA:  
**Farmers Have Too Low Knowledge to Protect and Benefit from Native Pollinators – Insight from Morocco** 27

- STEFANIE CHRISTMANN, MOULAY SHRIF SMAILI, ABDEL-LAH BENBYA, TOSHPULOT RAJABOV, ATHANASIOS TSIVELIKAS:  
**Farming with Alternative Pollinators Creates High Incentives for Farmers for Pollinator Friendly Agriculture** 28
- ISABEL MADALENO:  
**Flora Grown and Traded in Panama City, in the 16<sup>th</sup> Century and Nowadays** 29
- LINDA HILGERS, PHILIP BECKSCHÄFER, CHRISTOPH KLEINN:  
**Enhancing Biodiversity – Identification of Conservation Corridors in a Plantation Dominated Landscape in the Mekong Region** 30
- DÉBORAH OLIVEIRA, PATRÍCIA MELO, ARNE CIERJACKS, JARCILENE ALMEIDA-CORTEZ:  
**Where Are the Young Umbuzeiros? How Managed Areas Influence the Recruitment of *Spondias tuberosa* Câm. (Anacardiaceae) in Northeastern Brazil** 31
- EDUARDO ALBERTO LARA REIMERS, EDUARDO ANTONIO LARA RODRIGUEZ, JUAN MANUEL ZEPEDA DEL VALLE, ELOY FERNÁNDEZ CUSIMAMANI, ZBYNEK POLESNY, LUKAS PAWERA:  
**Ethnobotanical Survey of Medicinal Plants Used in the Zacatecas State, Mexico** 32
- ALEXANDR ROLLO, BOHDAN LOJKA, MARIE KALOUSOVÁ, BOHUMIL MANDÁK, MARIA MARGARIDA RIBEIRO:  
**Genetic Structure in Wild and Cultivated Populations of *Inga edulis* Mart. (Fabaceae) in Peruvian Amazon** 33
- STACY HAMMOND, IVA VIEHMANNOVÁ, JIRI ZAMECNÍK:  
**Slow-Growth *in vitro* Conservation of *Ullucus tuberosus* (Loz.), an Andean Tuber Crop** 34
- MIGUEL ALVAREZ, CONSTANZE LEEMHUIS, GEOFFREY GABIRI, KAI BEHN, SONJA BURGHOF:  
**Hydrological Gradients in a Tanzanian Floodplain: The Potential Use of Indicator Plants for Bio-Monitoring** 35
- SILKE LICHTENBERG, ELISABETH HUBER-SANNWALD, JUAN ANTONIO REYES-AGÜERO, UDO NEHREN:  
**The Use of Pau-Brasil (*Paubrasilia echinata* Lam.) for Making Violin Bows: A Social-Ecological System Analysis Linking Environment and Art** 36
- ANDREA RUEDIGER:  
**Securing Access to Seed – An Institutional Analysis of Informal Seed Assistance in Eastern Ethiopia** 37

MD KAMAL HOSSAIN, BARBARA STURM, ALEXANDER QUADT, OLIVER HENSEL: <b>A Sustainable Natural Resource (<i>Moringa oleifera</i>) in Tropical and Sub-Tropical Areas: An Intensive Literature Review</b>	38
HARRIET GENDALL: <b>Remembering ‘<i>Mauka</i>’: Biocultural Diversity Conservation and the Case of the ‘lost’ Andean Crop <i>Mirabilis expansa</i> (Ruíz &amp; Pav.) Standley</b>	39
DUNJA MIJATOVIC, MAEDEH SALIMI, HELGA GRUBERG CAZÓN, REUBEN MENDAKOR SHABONG, ALEJANDRO GONZÁLEZ ÁLVAREZ, SAJAL STHAPIT, STANLEY ZIRA, GHANIMAT AZHDARI, SONTANA MANEERATTANACHAIYONG, ALBERTO TARRAZA RODRÍGUEZ, EPSHA PALIKHEY, LAL WAKKUMBURE, NATALIA ESTRADA-CARMONA, TOBY HODGKIN: <b>Adaptive Management of Agrobiodiversity in Biocultural Landscapes: Experiences from the Field</b>	40
KERSTIN FISCHER, JULIET JABATY, ALIMOU CAMARA, SANDRA DIEDERICH, THOMAS HOENEN, ANNE BALKEMABUSCHMANN, ANDREAS MÜLLER, ROLAND SULUKU, KRISTINA MARIA SCHMIDT, CÉCILE TROUPIN, BASHIRU KOROMA, FELIXTINA JONSYN-ELLIS, NOEL TORDO, THOMAS C. METTENLEITER, MARTIN H. GROSCUP: <b>Ebola Foresight: The Role of Livestock and Wildlife Species in the Biology of Filoviruses</b>	42
TERESA ROJAS LARA, DANIEL MERDES: <b>Linking up Wildlife Conservation and Climate Change Mitigation: The Case of Orangutans in Indonesia</b>	43

---

## Building a Global System for *ex situ* Conservation of Crop Diversity

ELENA POPOVA, CHARLOTTE E. LUSTY, LUIGI GUARINO

*Global Crop Diversity Trust, Germany*

The Global Crop Diversity Trust (the Crop Trust) is an independent international organisation established in 2004 by the Food and Agriculture Organisation (FAO) and the international agricultural research centres (IARCs) of the CGIAR (formerly the Consultative Group on International Agricultural Research) as a worldwide response to the problems of food insecurity, poverty and environmental degradation. Specifically, the Crop Trust is raising an endowment to provide long-term funding for the conservation of priority collections of crop diversity around the world. At a time when environmental and human demands are placing an unprecedented strain on agriculture the world over, it is critical to conserve plant genetic resources for food and agriculture to guarantee that farmers and plant breeders continue to have access to the raw materials they need to improve and adapt their crops – to provide food and income for us all in the future, while preserving the environment. The Crop Trust endowment provides that guarantee. The Crop Trust and the endowment it manages constitute an integral part of the financial strategy of the International Treaty on Plant Genetic Resources for Food and Agriculture. The strategic *ex situ* conservation activities supported by the Crop Trust from its endowment (and from additional project funding) on the basis of its Fund Disbursement Strategy on the one hand, and the priority *in situ* activities supported by the Treaty's Benefit Sharing Fund on the other, are equally important, complementary efforts to conserve and sustainably use plant genetic resources for food and agriculture. The urgency of such efforts is increasing, not least because of pressure on food production systems from climate change.

**Keywords:** Agrobiodiversity, conservation, genebank

## Bee Pollinator Communities and Human Disturbance in West African Savannas – Implications for Crop Yield?

KATHARINA STEIN<sup>1</sup>, KATHRIN STENCHLY<sup>2</sup>, DRISSA COULIBALY<sup>3</sup>, ALAIN PAULY<sup>4</sup>, INGOLF STEFFAN-DEWENTER<sup>1</sup>, SOULEYMANE KONATÉ<sup>3</sup>, DETHARDT GOETZE<sup>5</sup>, STEFAN POREMBSKI<sup>5</sup>, KARL-EDUARD LINSENMAIR<sup>1</sup>

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In many parts of the world pollinators and pollination services are threatened by land use changes involving degradation of semi-natural habitats or the conversion into agricultural land. Such disturbances are often leading to lowered pollinator abundances or diversity thereby increasing risks to humans by e.g. lower crop yield. Our study is the first of its kind in West Africa to monitor bee community changes across gradients of human disturbance and the functional consequences thereof. Bee species richness, abundance and diversity was monitored by pan traps during 22 months covering two rainy and two dry seasons in 2014 until 2015. Traps were installed in savannah plots of varying disturbance intensities (low, moderate, high) and in nearby cotton and sesame fields. Species richness was stable at all sites. Whereas bee abundance increased with intensified land use, bee diversity decreased significantly. Bee communities in the moderate and high disturbed sites comprise only subsets of the communities in the least disturbed site. Crop yield in cotton was positively associated with bee abundance regardless of disturbance intensity. No correlation was found in sesame. Particularly wild bees were relevant for crop productivity even when honey bees were abundant. Hence, the presence of specific species in a pollinator community drives the positive pollinator abundance – pollination service relationship, in particular for fruit set. Retention of diverse bee communities is important because species are likely to vary in sensitivity to different disturbances, making service provision more stable. A clear spillover of bees from savannah into cotton fields was observed during the rainy season when crops are mass flowering indicating that agricultural areas serve as important food resources for bee species in times when resources in the savannah are scarce. Even though our study did not reveal negative effects of disturbance on crop yield, the results nevertheless emphasise the importance of the conservation and restoration of diverse pollinator communities to maintain their pollination service and hence human benefits.

**Keywords:** Abundance, bees, Burkina Faso, diversity, floral resources, pollination, seasonal variation, spillover, sub-Saharan Africa

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## Diversity of East African Wetland Vegetation: A Classification Based on Current and Historic Surveys

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Wetlands in East Africa are important ecosystems for biodiversity conservation and ecosystem service provisioning. Due to their suitability for crop production, the use of wetlands is getting increasingly intensified as food demand rises. In consequence, wetlands are at high risk of degradation, especially when land use changes include the establishment of drainage infrastructure. In order to project sustainable management strategies and conservation plans, it is crucial to understand structures and dynamics of wetlands. Plant communities reflect ecological conditions and degrees of disturbances and may hence be used as bio-indicators. While many published works have been focused on classification of East African wetland vegetation, consistent classification schemes for the region are still missing. We hence conducted detailed studies of vegetation in two different wetland ecosystems in East Africa. The first site is the lowland floodplain of the Kilombero river in Tanzania, which is characterised by Tropical Savannah climate and two distinct rainy and dry seasons. The second site is located in Central Uganda and consists of small inland valleys with a climate at the transition between Tropical Monsoon and Tropical Rainforest. While at both study sites patches of natural vegetation and long-term fallows can be found, cultivation of rice is the dominating form of land use. We sampled vegetation in nearly 400 plots, each 4 m<sup>2</sup> size. They were chosen along gradients of land use intensity and flooding duration. A classification of the plots was conducted based on species composition using the Cocktail-Classification method. Formal definitions of plant communities were developed and compiled to an expert system and then applied in the classification of data stored in the vegetation-plot database "SWEA-Dataveg" (<http://www.givd.info/ID/AF-00-006>). In the study area, 18 plant communities were identified, of which most belong to the phytosociological classes of Phragmito-Magno-Caricetea (marshes and reeds) and *Oryzetea sativae* (weed and pioneer vegetation). While the two study sites did not share any communities, 9 were recognised in the database with the developed definitions. Integration of these results and literature resulted in an overview of East African wetland vegetation with reference to ecological conditions, degree of disturbance and geographic distribution for each unit.

**Keywords:** Classification, East Africa, land use changes, plant communities, vegetation ecology, wetland

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## Plant Communities Changes in Relation to Land Uses and Soil Properties in Malinda Wetland, Tanzania

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In East Africa, demographic growth, inter-generational inheritance of land, increasing land scarcity in the highland areas, degradation of upland soils and inter-annual rain variability is increasing cropping pressure on seasonal and nearly permanent wetlands. This study was carried out between 2008 and 2016 in order to find the changes of plant communities in Malinda wetland due to intensity of land use which results into changes of soil properties which impacts the functions of wetland ecosystems and on potential productivity of the soils. A first survey and plant communities characteristics in the area was firstly done in 2008 and a rapid appraisal with key informants was carried out to determine the characteristic land uses and to collect information on land use history of the area. Four land use types were determine which include unused part with domination of wetland vegetation, fairly used area with minimal grazing during dry period of the year, high intensity used area dominated by horticulture and fallow land which has been left after use or is used for yearly grazing. According to preferential sampling, 40 plots of size 10 m<sup>2</sup> representing the main types of land uses were selected. In those plots all species and their estimated abundance as percentage cover were recorded. In each plot soil samples of the layer 0–15 cm were taken for soil chemical analysis. The same sampling techniques and procedure were repeated in the year 2016. The vegetation was classified by using hierarchical clustering technique and the relationships between species composition (land uses and plant communities) and soil properties of the wetland. The canonical correspondence analysis (CCA) was applied and the vegetation was classified into ten plant communities (clusters), five of them were weed communities of croplands while the remaining plant communities were from fallow, grazing land and unused part of wetland. There was no great difference in vegetation composition and plant communities obtained between the period of eight years. Both showed almost the same species composition and the plant communities were determined by soil exchangeable K, electric conductivity and pH according to ordination analysis.

**Keywords:** East Africa, land degradation, soil properties, use intensity, wetland

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## **Agroforestry-Based Restoration and Enhanced Resilience of Agricultural Production through Adaptation of Smallholder Farming Systems, Nicaragua**

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Rural communities in the Dry Corridor of Central America are highly vulnerable to the consequences of soil and land degradation, and climate change. Smallholder farmers traditionally produce grain crops on steep hillsides through slash-and-burn agriculture, increasingly combined with small-scale cattle farming. Only 3% of the original forest cover remains. The ARA (Agroforestry for Restoration of Agroecosystems) project aims to restore degraded land, enhance agroecosystem productivity, profitability and resilience, and generate ecosystem services through agroforestry systems. Between 2008 and 2013 a platform of 25 on-farm experiments, representing three different communities in the Dry Corridor of Nicaragua, was established. The platform has served different objectives: (i) participatory adaptation of agroforestry systems; (ii) research to understand and quantify the impacts of agroforestry-based interventions on ecosystem services, including crop production, and farmer revenues (iii) training of farmers and technicians and knowledge sharing to facilitate out scaling. Agroforestry systems included Quesungual, a maize-bean system intercropped with trees and established through selective clearing and pruning of regenerated trees. Five land use systems were established/selected on the participating farms: Traditional slash-and-burn maize-bean system (TCS), Quesungual Agroforestry (AFS), Secondary forest (SF), Naturalized pastures (NP) and Improved silvopastoral systems (SPS). Crop and forage production, soil fertility, soil erosion, C sequestration and biodiversity was monitored from 2013 to 2016. Results confirm that AFS and SPS can improve tree diversity conservation and carbon storage, while maintaining (maize) or increasing (bean) production. Collection of detailed soil, plant, microclimate and meteorological data allowed for the modelling of tree-crop interactions and land use scenarios to further evaluate impacts of Quesungual on ecosystem services.

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A detailed study on adoption rates and factors at the community level showed steadily increasing levels of adoption (up to 39 % of households in 2016). Strong support through capacity building was identified as a key factor to further enhance adoption. Despite increasing adoption rates and beneficial impacts of AFS and SPS on ecosystem services and production, further improvements in production systems are needed. A synthesis of key lessons from the project and reflections on future directions and research priorities will be presented.

**Keywords:** Adoption, agricultural productivity, agroforestry, Central America, ecosystem services, land restoration, Nicaragua, resilience, soil fertility

## **Vegetation-Based Indicators for Assessing Ecosystem Services of Cacao Agroforestry Systems, Buffer Zone of Abiseo River National Park, Peru**

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This research aimed to identify vegetation structural attributes capable of performing as indicators for the assessment of support and provision services of the cacao agroforestry systems. This was done by setting up a comparison between the cacao agroforestry systems, the cacao plantation, and the natural forest in the buffer zone of the National Park 'Rio Abiseo', in the Peruvian amazon. The comparison was carried out under the assumption that structural attributes of the vegetation, such as the tree diversity (richness and evenness) and composition, forest structure (DBH, height, vertical layers, shrub and herbaceous cover, and diversity and composition of saplings) and coarse woody debris (snags, logs, and litter depth) can be indicative of supporting and provisioning services. The supporting services were focused on the provision of suitable habitat for the jaguar (*Panthera onca*) and the San Martin's titi monkey (*Callicebus oenanthe*) while the provisioning services focused on the average monthly income (USD per ha) from cacao production. The structural attributes were measured and compared in modified Whittaker plots (0,1 ha) set in the cacao agroforestry systems (19 plots), cacao plantations (21), and natural forests (20). A principal component analysis and a constrained correspondence analysis (with a permutation test) were used to compare different systems. These analyses allowed the identification of the presence of a shrub cover, the layer of trees between 16 and 20m tall, the presence of snags, the average tree height, and the layer of trees between 5 and 15m tall, as significant vegetation structural attributes for the assessment of the ecosystem services in the different systems. These attributes can guide the decision-making process in the buffer zone of the National Park to assure habitat provision, particularly for the endemic species of titi monkey of San Martin. At the same time, it can assure the sustainable production of cacao and the livelihoods of human communities that depend on the ecosystem services of the buffer zone of the National Park Rio Abiseo.

**Keywords:** Cacao agroforestry systems, ecosystem services, indicators, National Park Rio Abiseo, Peruvian amazon

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## Farmers Have Too Low Knowledge to Protect and Benefit from Native Pollinators – Insight from Morocco

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In 2016 The Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) showed that agricultural production is now twice as dependent on pollinators than five decades ago, but pollinator decline accelerates globally, in particular in agricultural lands. Farmers cannot protect, what they do not see or recognise or value. Knowledgeable farmers are crucial for pollinator protection. In 2016 the knowledge of 110 male and female smallholder farmers (0.4 – 2.5 ha) in the Rabat-Salé-Kenitra region (Morocco) has been assessed by a standardised questionnaire. On average, farmers know only 1.4 pollinator species except honeybees. 23 out of 110 farmers had collaborated with beekeepers, but not for improved pollination of their crops. They had invited the beekeepers to bring hives, because according to local arrangements a farmer providing flowers gets a share of the honey as in kind payment. Despite availability in their agricultural lands no farmer is able to recognise nests of pollinators or predators. Though all farmers produced at least one pollinator dependent crop, only 19 % were aware that they need pollinators in their fields. They did not know for which crops pollination is essential, for which crop pollination has great, modest or little impact, they were e.g. much more concerned about pollination of tomato than of apple. As apple flowers in early spring, pollination by honeybees is often hampered by rain or cold days without sun. Farmers lacking knowledge might take wrong decisions in case of crop failure. All farmers enlarged fields reducing valuable pollinator habitats in field edges since the year 2000. Also the farmers increased the use of insecticides and fungicides on average by 54 % since 2000. There is very little literature on farmers' knowledge on pollinators, but according to the samples the knowledge in Morocco is comparatively low. There was nearly no difference between literate and illiterate farmers. Therefore, obligatory lessons on pollinators is recommended for primary and secondary schools. Involvement of mass media would be useful.

**Keywords:** Formal education, habitat, honeybees, IPBES, wild pollinators

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## Farming with Alternative Pollinators Creates High Incentives for Farmers for Pollinator Friendly Agriculture

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Currently, environmental research on pollinator decline does not trigger broad protection of pollinators in particular in agricultural landscapes. Prevailing environmental recommendations, e.g. seeding wildflower strips in and between fields, don't take farmers' interests into account. Farmers prefer income from the entire area and they regard wildflowers as weeds potentially spreading their seeds all over the field. Whereas the new agricultural Farming with Alternative Pollinators (FAP) approach uses marketable plants for habitat enhancement and avoids spread of weeds. FAP triggers farmers' motivation to enhance habitats in fields based on evidence of increased income. FAP measures the impact of enhanced habitats (25 % of the field) on the diversity of pollinators and predators and on the total net income in comparison to control fields having the main crop on 100 % of the field. Pilot projects in Uzbekistan with cucumber and sour cherry as main crops and in Morocco with cucumber as main crop proved high increase of yields of the main crop and higher income per surface based on higher diversity and abundance of pollinators and predators in FAP-fields. In total income from FAP fields was more than double in comparison to control. The incentive of large income gain makes FAP scalable. FAP obviates the need to reward farmers for pollinator-friendly practices. As insect species highly differ in Central Asia and North Africa the approach proved replicability. Trials on more crops are recommended. In case they demonstrate substantial income increases as well, FAP might have high potential to protect pollinators and simultaneously enhance food security. Currently, the increase of horticulture production is mainly based on increase of area, whereas FAP increases the productivity per ha. Thus FAP might reduce the loss of forests and rangelands for establishment of additional fields and orchards. FAP is applicable also in low income countries, which cannot afford subsidies as e.g. the European Union pays.

**Keywords:** Habitat zone, intrinsic motivation, marketable plants, self-sustaining

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## Flora Grown and Traded in Panama City, in the 16<sup>th</sup> Century and Nowadays

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Panama City is located in the Pacific coast of the isthmus that united North and South America somewhere between 15 and 3 million years ago. The capital city of Panama is a tropical modern urban centre that registers about 1,750 mm of rain per year, which favours the growth of food, medicinal herbs, fruit trees and ornamental species in gardens and pots. In early 2017, the University of Lisbon conducted a scientific mission to Panama to survey the local flora, in order to compare this flora with the plant species mentioned in the 16<sup>th</sup> century manuscript of Gonzalo Fernández de Oviedo (1526), following a long time project initiated in Brazil in 1997 by the Portuguese Tropical Research Institute. The main objective of the research was to assess the availability of local food, spice and medicines in the early years of European colonisation and to evaluate the contribution of the Portuguese and the Spanish peoples to the evolution of flora consumption and therapeutic application. The current survey included two categories of informants: i) three (3) gardeners devoted to food and medicines cultivation inside the urban area; ii) forty-seven (47) formal and informal traders found in markets, supermarkets, or pharmacies. The results showed that 171 different plant species are offered to the public today against 55 mentioned by the chronicles in early colonisation days. More than half of the species have medicinal uses in our days and about one third are consumed as food. The final research aim is to build a database that permits to study the evolution of Latin American flora and their uses throughout times.

**Keywords:** Flora, food, Latin America, medicines, Panama, spices

## Enhancing Biodiversity – Identification of Conservation Corridors in a Plantation Dominated Landscape in the Mekong Region

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The rapid expansion of rubber tree plantations (*Hevea brasiliensis*) and cash crops across southern subtropical China puts high pressure on natural forests and their biodiversity. Xishuangbanna Prefecture in the South of Yunnan Province is particularly affected as here rubber monoculture plantations currently cover about 440,000 ha and have replaced large shares of traditional land use systems and natural rainforests over the past 40 years. Today, contiguous blocks of mature natural forest are confined to the prefecture's nature reserves which are, however, isolated. Further, the ongoing transformation of the lands surrounding the reserves and the encroachment of plantations into them, continues to increase the separation of reserve dwelling plant and animal populations, impeding movements and interactions between them. In order to reconnect isolated populations, it is necessary to establish wildlife corridors that prepare the grounds for the dispersion of organisms. We identified potential wildlife corridors for three functional groups of species: (a) large mammals, (b) primates and (c) birds. Group specific resistance values that quantify the species' likelihood to migrate through certain land cover were derived from a literature review and an up-to-date land cover map was employed for corridor mapping using least-cost models. The identified least cost paths clearly displayed the high degree of isolation of all reserves since none of the routes connected two reserves on the shortest way. Instead, the model primarily proposed detours integrating fragmented forest remnants into the corridors. Conservation corridors for large mammals corresponded mostly with those for primates, solely the corridors for birds differed. The corridors for primates had most similarities with both other groups and were therefore suggested to be appropriate for the greatest variety of species. Our results illustrate the high degree of isolation of nature reserves in Xishuangbanna and confirm the urgent need of reconnecting them through corridors in order to protect, preserve and enhance the remaining biodiversity and counteract the ecological threats from the expansion of rubber plantations.

**Keywords:** Cost-based corridor, land transformation, landscape connectivity, landscape resistance values, least-cost path, Linkage Mapper, rubber plantation, Xishuangbanna

## Where Are the Young Umbuzeiros? How Managed Areas Influence the Recruitment of *Spondias tuberosa* Câm. (Anacardiaceae) in Northeastern Brazil

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*Spondias tuberosa* Arr. Cam. is an endemic fruit-bearing tree of the Brazilian semi-arid region with great socio-economic and environmental importance. This species is a source of sustenance for local people and small farmers, especially during the dry season. *S. tuberosa* also provides food for wild and domesticated animals, playing an important role to environment. However, there is a lack of seedling recruitment in their natural environment, which has been attributed to seed predation, low seed germination and establishment, and the irregularity of rainfall in the region. Furthermore, land use change and overexploitation have been hypothesized to cause a risk of extinction in this species. In this study, we aimed to assess the population trends, seed production and predation, as well as the germination in greenhouse, of *S. tuberosa* from agricultural (AGR) and protected (PA) areas in a seasonal tropical dry forest of northeastern Brazil. We selected 25 adult individuals and from each tree we measured the diameter. Under the canopy, we counted and collected the seeds of the current season. In a greenhouse, these seeds were germinated and had their growth accompanied. Our results showed that in AGR all the diameter size-class were represented while in PA the first two size-class showed a lack of individuals. The production of seeds was not different between these two areas although the number of seed m<sup>-2</sup> was higher in AGR. Trees located in AGR usually occurred isolated, which may explain the fact that the rate of seed predation was more intense in these areas. Seed size also was bigger in AGR and the seedlings from these seeds were more vigorous than the ones from PA. We found seedlings exclusively in agricultural areas, probably due to abundance of water and soil nutrients and to absence of wild or domesticated animals. Our results clearly show that somehow the species depends on human action for its regeneration. Thus, researchers and stakeholders (local people) should combine efforts to develop strategies for species conservation.

**Keywords:** Brazilian seasonal tropical dry forest, population dynamics, regeneration



## Ethnobotanical Survey of Medicinal Plants Used in the Zacatecas State, Mexico

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The medicinal plants used by communities across all of people in Mexico have an important role in the local health care system. The use of wide plant diversity contributes to the socio-ecological resilience and cultural diversity of each community but there are still regions without documented plant use. The aim of this study was to record, analyze and identify the medicinal plant knowledge of the local people in the state of Zacatecas, Mexico. A total of 132 semi-structured interviews were conducted. The informants were aged between 20–86 years and the gender proportion was 44 % male and 56 % female. Medicinal plants were identified taxonomically, and data were analyzed and compared using Relative Frequency of Citation (RFC), Family Importance Value (FIV), Cultural Importance Index (CI), and Informant Consensus Factor (ICF). Results show that 96% of respondents actively use plants. A total of 168 medicinal species belonging to 151 genera and 69 botanical families were documented. The family Asteraceae (20 species; FIV=15.15) represented the highest number of species. The majority of herbal remedies are used orally and predominantly in the form of infusion (52 %). The most culturally important species was *Matricaria chamomilla* L., followed by *Arnica montana* L. and *Artemisia ludoviciana* Nutt. Diseases of the reproductive system reached the highest consensus ratio (ICF=0.81). The highest number of Uses Report (N=389; 25 % of all UR) as well as plant species (68) were determined for diseases of the digestive and gastrointestinal system. This is the first explorative and analytic study conducted dealing with the relative importance of medicinal plants based on quantitative tools in the semi-arid region of Zacatecas, México. The results revealed a high diversity of medicinal plant species and their uses in local traditional medicine. The new generation in the sample studied maintains ancestral knowledge of the use of medicinal plants. The practice of traditional herbal medicine is also applied as a complementary treatment for common and chronic diseases. This practice is co-evolving with the modern health system due to lack of accessibility and perceived low effectiveness of conventional medicine.

**Keywords:** *Arnica montana*, ethnomedicine, human health disorders, *Matricaria chamomilla*, medicinal plants, traditional medicine

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## Genetic Structure in Wild and Cultivated Populations of *Inga edulis* Mart. (Fabaceae) in Peruvian Amazon

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*Inga edulis* Mart. has been improved through history by human selection focusing on the edible fruit, and, also, to provide shade for other crops. We aimed at comparing wild and cultivated *I. edulis* populations' genetic structure spanning the Peruvian Amazon. We evaluated a total of 259 trees, 197 cultivated and 62 wild, sampled from 27 populations. For each individual a voucher specimen was kept. The total genomic DNA was extracted for each sample and genotyped with four microsatellite primers.

We identified 71 alleles, with an average of 17.8 alleles per locus. For the 27 populations with at least 5 samples, the average number of alleles was 5.7, the average allelic richness 4.4, the observed heterozygosity 0.59, and the expected heterozygosity 0.69. The heterozygote deficit was non-significant, but the inbreeding coefficient was 0.153. Twelve populations were not in Hardy-Weinberg equilibrium. These populations were distributed randomly across the *I. edulis* sampled range and across cultivated and wild populations. We compared the wild vs. the cultivated populations, and significant deviation from the null expectation emerged. The allelic richness and the observed heterozygosity were lower in the group of cultivated populations. The level of differentiation among populations was significantly higher in the cultivated compared to the wild populations.

A hierarchical analysis of molecular variance revealed that a majority of the genetic diversity was partitioned within populations (78.8%), 14.3% was partitioned among populations within groups (wild and cultivated) and 6.9% was partitioned between cultivated and wild groups. To further assess the population structure, we estimated the number of genetic clusters (K) and to fractionally assign individuals sampled from cultivated and wild populations to the inferred groups. Due to the weak population structure, we used a "locprior" model, which incorporated a priori sampling information. Two groups of populations were used as priors, the cultivated and the wild populations. The number of clusters (K) was set at each value from one through twenty-eight, and the simulation was run ten times at each K value to confirm the repeatability of the results. According to the Bayesian structuring results we inferred that the cultivated material in Peruvian Amazon has different origins.

**Keywords:** DNA, genetic structure, *Inga edulis* Mart., microsatellite locus, PCR, peruvian Amazon, population

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## Slow-Growth *in vitro* Conservation of *Ullucus tuberosus* (Loz.), an Andean Tuber Crop

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*Ullucus tuberosus* (Loz.) of the Basellaceae family is a perennial tuberous crop, originating from the Andean region where it is cultivated for its edible tubers. The species is vegetatively propagated, which causes standard conservation of its genetic material difficult to perform using conventional methods. An efficient tool for conservation of vegetatively propagated plants represents slow-growth *in-vitro* method that ensures the genetic resources secure maintenance and availability for farmers and plant breeders. This study focuses on optimizing the slow-growth *in-vitro* protocol for medium-term conservation of the species using MS storage culture media supplemented with three osmotic agents at different concentrations: sorbitol (1, 2 and 3%, w/v), mannitol (1, 2 and 3% w/v), and sucrose (1, 3, 6, 9 and 12% w/v); or abscisic acid (ABA) (1, 2 and 3 mg l<sup>-1</sup>). MS without osmotics and hormone was used as control. Forty plants per treatment including control was established, twenty were maintained at growing temperature of 5°C and twenty at 17°C. Plant height (cm), number of leaves, shoots and numbers of roots were evaluated for four consecutive months as a primary study within a longer period experiment. Results showed that the appropriate temperature for growth reduction while maintaining the vitality of plants for medium-term conservation of the species is 5°C, while temperature of 17°C is not appropriate as the plants grow at an exponentially higher rate. Mannitol 3%, sucrose 12 and 9% and ABA 3 mg l<sup>-1</sup> concentration yielded the best results in terms of growth reduction and maintenance of plant vitality during conservation when compared to the control and therefore appears to be the most effective for medium-term conservation of the species. However, further evaluation will be carried out over a 12 months period to determine what supplement is most effective in time and to have a fully optimised protocol. Conservation of this species is important, as it will ensure the constant availability of the species for both farmers and plant breeders.

**Keywords:** Abscisic acid, mannitol, medium-term conservation, osmotic agents, sucrose, *Ullucus tuberosus*

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## Hydrological Gradients in a Tanzanian Floodplain: The Potential Use of Indicator Plants for Bio-Monitoring

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While flooding periods curtail cultivation, extended soil moisture availability during dry seasons makes floodplains and riparian environments suitable for seasonal cropping and other agricultural uses. Unsustainable cultivation practices coupled with the establishment of drainage structures can however result in degradation of soil physical properties and hence overall soil water availability. This can consequently result in productivity decrease of agro-ecosystems. Also from the ecological point of view, altering hydrological regimes of floodplains can lead to disruption of habitat integrity for living organisms. Thus, implementation of bio-indication using vascular plants may provide a practical tool for quick assessment of degradation status of wetlands in large areas. In order to evaluate the potential capacity of vascular plant species for bio-monitoring, we assessed the shallow groundwater regime of a hydrological gradient in the floodplain of the Kilombero River around Ifakara (Tanzania). The area is mainly characterised by rice cultivation. Four hydrological indices were calculated from shallow groundwater monitoring time series data (March 2015 to June 2016) from 10 piezometers located along the hydrological gradient in the floodplain. These indices describe the overall shallow groundwater availability, their variability, flooding intensity and duration. Vegetation samples were collected in the proximity of piezometers and linked to the respective hydrological variables. The prevalence (optimum growth conditions) of the recorded species along hydrological gradients was estimated by weighted averaging. While dynamics of shallow groundwater table is complex and difficult to reduce to one variable without losing information, flooding regimes showed a clear positive linear relation between duration and intensity. Flooding duration is therefore a good proxy of flooding regimes, especially in sites without installed flooding monitoring devices. Though most of the species had an optimum around intermediate hydrologic conditions, some species may indicate different combinations of levels such as general low water table regimes with strong fluctuations (e.g. *Panicum fluviicola* and *Heliotropium indicum*) or high, more stable regimes (*Acmella uliginosa* and *Ammannia baccifera*). Similarly there is a continuous sequence of species indicating low flooding intensity and short flooding periods (*Eragrostis ciliaris* and *Indigofera hirsuta*) to higher flooding intensity for longer periods (*Ethulia paucifruca* and *Persicaria senegalensis*).

**Keywords:** Croplands, ecological modelling, land use, plant ecology

## The Use of Pau-Brasil (*Paubrasilia echinata* Lam.) for Making Violin Bows: A Social-Ecological System Analysis Linking Environment and Art

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*Paubrasilia echinata* Lam. from the legume family Fabacea, in Portuguese known as pau-brasil, is the national tree of Brazil. Its precious wood is used worldwide as raw material for violin bows. For professional musicians, no alternative wood seems to meet the high-quality standards of pau-brasil. Due to the historical and current overexploitation of pau-brasil in the Atlantic Forest of Brazil, this species is highly endangered. The dependence of traditional manufacturing of bows for violins on the threatened species of pau-brasil and an increasing mass production of bows have resulted in a challenging conflict. Raw material scarcity, unequal access to the raw material and different legislative regulations on the local, regional and global scales are main aspects of the problem. This situation has led to cross-arching challenges in the biophysical (decline of natural populations of *P. echinata*) and socioeconomic dimensions (conservation, management, socio-political organization associated with an increasing market of pau-brasil wood). Thus, it represents a complex problem on local, regional and global scales. Therefore, the analysis of this problem requires a comprehensive framework of a complex system, in a social-ecological system's (SES) context. In the case of a continuous use of pau-brasil in the production of violin bows, it is pertinent to identify and analyze the role of key actors and factors that contribute to the dynamics of this particular SES, to identify both possible system states and their resilience and scenarios that put pau-brasil and its use in bow making potentially at risk on the long-term. Hence, the current study includes a temporal analysis of the socioeconomic, political, ecological and legislative backgrounds and drivers, which allowed us to understand the complexity of the problem more precisely.

**Keywords:** Pau-brasil, *Paubrasilia echinata*, social-ecological system, violin bows

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## Securing Access to Seed – An Institutional Analysis of Informal Seed Assistance in Eastern Ethiopia

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Seed is an essential input for production in small-farming households. Especially under conditions of environmental stress, including periodic drought, secure access to seed is central to improving food security and to the livelihood of vulnerable, rural households. Highly developed informal seed systems play an important role in securing access to seed and maintaining a high level of crop-genetic diversity in eastern Ethiopia and beyond.

We present a mixed-methods study of a highly developed informal seed insurance network among subsistence-oriented small-farmers in one highland and one midland district in the West Hararghe zone of eastern Ethiopia. A particular focus is given to the immaterial aspects of this elaborate mutual aid practice, including explicit and implicit rules and norms, motivations, sanctions or the underlying enforcement mechanism. Based on a survey and interviews with 146 farmers, we find that the overwhelming majority of small farmers actively participate in informal seed assistance by giving or receiving small quantities of seed without cash or in-kind compensation, especially in planting seasons after a drought. Denial of seed is highly exceptional and only reported in communities in which off-farm seed is supplied by a local patron. The analysis suggests that the institutional design of informal seed assistance, compared to other practices of mutual aid, sets incentives to use this *ex-ante* insurance instead of *ex post* food or cash assistance after harvest. Moreover, we argue that the seed assistance through gifts is practised to facilitate access to crop genetic resources in a centre of crop origin and diversity.

**Keywords:** Ethiopia, genetic resources, informal institutions, seed, small farmers

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## A Sustainable Natural Resource (*Moringa oleifera*) in Tropical and Sub-Tropical Areas: An Intensive Literature Review

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*Moringa oleifera* is a species of the Moringaceae family and mostly available in the tropical and subtropical areas including Bangladesh, Nepal, India, Pakistan, Afghanistan and some African countries. It is widely contributing to sustainable food, agriculture and medicine development as well as sustainable aquaculture. MO is a promising natural food source in the tropics because of its availability even in the end of dry season when other foods are typically scarce. Furthermore, MO trees have been advocated by the Educational Concerns for Hunger Organisation as a “natural nutrition for the tropics”, especially among infants and nursing mothers. This literature review research has been conducted with more than 30 internationally published research articles. It has been already proven that the MO tree is one of the most underutilized tropical crops because of lack of awareness, although it has multidimensional applications and functionalities including antioxidant, anti-diabetics and antibacterial activities. Apart from that, MO leaves extract shows the better results in a comparison study of the antimicrobial activities of sea fish preservation compared to brine solution. On the other hand, the entire MO trees (e.g. leaf, shoot, flower, pod, seed and root) are using in numerous applications including traditional diets. Also, the dried MO leaves can be preserved for a longer period without any preservative and adverse nutritional losses. Hence, drying can be done using the economical household appliance as well as commercial drying techniques. Above scientific evidence gives an indication that the MO grown for economic purposes as well as on a commercial scale, also the creation of employment, reduction of poverty and the rural development. This review research work would deliver the key indications and background for the future research.

**Keywords:** Economic and sustainable development, *Moringa oleifera*, natural resource

## Remembering ‘*Mauka*’: Biocultural Diversity Conservation and the Case of the ‘lost’ Andean Crop *Mirabilis expansa* (Ruíz & Pav.) Standley

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The so-called ‘lost’ crop “*mauka*” (*Mirabilis expansa* [Ruíz & Pav.] Standley) is a highly endangered and chronically understudied species of root vegetable native to the Andes. Carried out in Peru, in collaboration with the International Potato Center (CIP) and the National Institute for Agricultural Innovation (INIA); this in-depth ethnobotanical case study is the first to assess both explanations for the decline of the crop and approaches to its conservation. Emphasis is placed on farmers’ perspectives, which were distilled from 40 interviews conducted with Andean farmers (26 actively cultivating mauka and 14 who were familiar with or had given up cultivating the crop). *Mauka* was found in Ancash, Huánuco and Puno – three regions of Peru that had previously been under-explored in terms of mapping the crop’s distribution – and a total of 21 germplasm accessions were collected for *ex-situ* conservation; several of which constitute morphotypes new to scientific research. The ‘lost’ crop case study was framed by a broader discussion addressing processes inherent in biocultural diversity generation and loss, particularly with relation to agriculture; which found ‘cultural memory’ and ‘situatedness’ to be important considerations for the design of effective conservation projects. It is argued that despite suffering from severe genetic erosion and loss of associated ethnobotanical knowledge, *mauka* is worth conserving, and has greater potential than originally thought; specifically in a gastronomic context. As part of the study, *mauka* was introduced to chefs at Central Restaurant (Lima, Peru) – No. 4 of the World’s 50 Best Restaurants in 2016 – who carried out gastronomic experiments with it and have now begun working with local farmers to revalue this ancient crop. *Mauka* could well have an important part to play in the ‘cocina novoandino’ gastronomic movement; a new wave of cooking which centres on the rediscovery of native Andean ingredients and associated cultural customs.

**Keywords:** Biocultural diversity, cocina novoandina, crop conservation, cultural memory, gastronomy, lost crop, *Mauka*, *Mirabilis expansa*

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## **Adaptive Management of Agrobiodiversity in Biocultural Landscapes: Experiences from the Field**

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Agrobiodiversity makes up part of the adaptive capacity and resilience of biocultural landscapes; it allows for continuous innovation and evolution in response to new environmental challenges. Local communities, consciously or unconsciously, influence agrobiodiversity through various management and cultural practices. In this study, we combine agrobiodiversity conservation approaches and social-ecological systems thinking to explore the adaptive management of agrobiodiversity in eight distinct biocultural landscapes around the world, including pastoral, agroforestry and high mountain sites in Bolivia, Cuba, India, Iran, Nepal, Sri Lanka, Thailand, Zimbabwe. Adaptive management is a process of community decision-making about diversity that integrates new experiences and knowledge into management practices to increase resilience, and involves adjustments in response to new experiences and observations. Adaptive management largely depends on the collective engagement of community members through local institutions that can take different forms, from specific management plans to shared sets of beliefs. Data were collected in household surveys, focus group discussions, and through participant observation and other methods. The results of our study show the evolution of local institutions that guide the processes of adaptation in the face of climate change and uncertainty, and ensure equitable sharing of resources. Better understanding of adaptive management of agrobiodiversity can

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help identify constraints and opportunities for strengthening climate change resilience through the strategies of diversification, conservation and restoration. We provide recommendations for initiatives targeting landscapes that comprise the global biocultural heritage and serve as reservoirs of crop genetic resources of critical importance for future food security and sustainable development.

**Keywords:** Adaptive management, agrobiodiversity, biocultural landscapes, resilience

## **Ebola Foresight: The Role of Livestock and Wildlife Species in the Biology of Filoviruses**

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The Ebola virus disease (EVD) epidemic in West Africa (2013–2016) has been the largest known EVD outbreak in history. More than 28,000 confirmed cases of EVD and more than 11,000 deaths have been reported in the three most severely affected countries Sierra Leone, Guinea and Liberia. The unprecedented dimension of the epidemic caused disastrous economic and humanitarian consequences for the local population.

Human-to-human transmission has been the predominant route of transmission responsible for the rapid spread of the virus. However, the zoonotic origin of EVD outbreaks has been known for a long time and contact of humans to infected wildlife and their infectious body fluids, such as blood or excretions, is thought to facilitate the initial spillover into the human population. Fruit bats have been postulated to be the wildlife reservoir for Ebola virus. With regard to other animal species, there is a lack of knowledge concerning their susceptibility and potential role as intermediate hosts for Ebola viruses.

In the “Ebola Foresight” project, a project in close collaboration between the Friedrich-Loeffler-Institut (FLI), the Institut Pasteur in Guinea, the Sierra Leone Agricultural Research Institute, and the Njala University in Sierra Leone, we aim to study the role of livestock, domestic animals and wildlife as potential hosts in filovirus infection. Funded by the German Federal Ministry of Food and Agriculture, the project furthermore aims to build capacities in the African partner laboratories by training of local PhD students and laboratory staff. Diagnostic tools such as serological assays and novel sequencing techniques will be implemented in the African laboratories and will enable rapid specific responses to future outbreaks of zoonotic diseases. In addition, these techniques are leveraged to provide first answers to the scientific questions of the project. Complemented are these studies in the affected countries by laboratory studies at the FLI. In the long term, the project will enable the African partners to establish successful research projects, as well as to provide insight into the role of livestock and wildlife species in the biology of Filoviruses.

**Keywords:** Capacity building, diagnostic assays, Ebola virus, filoviruses, livestock, West Africa, wildlife

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## Linking up Wildlife Conservation and Climate Change Mitigation: The Case of Orangutans in Indonesia

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Tropical peat swamps provide numerous environmental services and contain 30 % of the world's sequestered (or terrestrial) carbon. Indonesia has 50 % of the world's tropical peat swamp. However, Indonesia peatlands are under pressure due to land use change, deforestation and fire occurrence. Indonesia is one of the top green greenhouse gas (GHG) emitters with about 2 GtCO<sub>2</sub> equivalents per year. Peatland and forest fires are by far the largest contributors to Indonesia's GHG emissions. In 2015, approximately 2.6 million hectares of land in Indonesia were burned, half of it on peatlands. Therefore, at the COP 21 in Paris the Indonesian government announced plans to ban new developments and forest clearing in peatlands. Moreover, the government instructed to rewet drained areas by blocking drainage canals in order to reduce CO<sub>2</sub> emissions.

At the same time, efforts are made by the worldwide biggest primate conservation NGO, Borneo Orangutan Survival (BOS) to contribute to the conservation of the Bornean orangutan and its habitat through the involvement of the local population. One of the intervention areas is Mawas, located within the ex-Mega Rice Project in Central Kalimantan. Mawas encompasses around 300,000 ha, most of them peatlands, and is the home to one of the last tracts of forest supporting wild orangutans. An estimated 3,000 wild orangutans and many other fauna and flora can be found in this area. A direct link to GHG mitigation is given through the role of Mawas as an important storage of giga-tonnes of sequestered carbon. Wildlife conservation activities involving forest conservation, reforestation and research thus unfold a direct positive impact on GHG mitigation.

This paper presents current work of BOS Foundation in cooperation with BOS Germany and other international organisations, central and local governments, as well as local communities. The work focus on combined forest conservation and forest landscape restoration activities with Orangutan habitat protection in Mawas. Until now, reforestation of more than 40 ha is completed and 27 canals are blocked, which represent a total of 58.4 Km of drainage canals. These actions contribute to rewetting of 1500 ha, which in turn is protecting an estimated area of 5000 ha of community forest. Moreover, new proposals, which seek to combine REDD+ activities with community development and Orangutan protection are in preparation.

**Keywords:** Borneo, climate change, Orangutan, peatlands, wildlife

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# Land use and land use change

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## Oral Presentations

- MICHAEL THIEL, ALEJANDRA NARVAEZ VALLEJO, GERALD FORKOUR, MICHELLE UDER, CHRISTOPHER CONRAD:  
**Remote Sensing Based Mapping of Crop Rotation Systems in the Sudanian Savannah of West Africa** 48
- PYI SOE AUNG:  
**Changes in Local Land Tenure System in Response to Swidden Transformation in Southern Chin State, Myanmar** 49
- DIANA SIETZ, JENNY ORDOÑEZ, MARCEL KOK, PETER JANSSEN, HENK HILDERINK, PABLO TITTONELL, HAN VAN DIJK:  
**Nested Archetypes of Vulnerability in African Drylands: Where Lies Potential for Sustainable Agricultural Intensification?** 50
- MARC COTTER, KEVIN THELLMANN, SABINE BAUMGARTNER, GEORG CADISCH, FOLKARD ASCH:  
**Identifying Tipping Points in the Supply of Ecosystem Services in Rural Environments of South-East Asia** 51
- ANITA HEIM, AILI PYHÄLÄ:  
**Farming Inside a National Park – What Is the Way Forward?** 52

## Posters

- ARCHANA RAGHAVAN SATHYAN, CHRISTOPH FUNK, THOMAS AENIS, PETER WINKER, LUTZ BREUER:  
**Climate Vulnerability Assessment and Sensitivity Analysis in Rainfed Farming Communities of Kerala, India** 53
- WILLIAM NKOMOKI, JAN BANOUT:  
**Land Conservation and Food Security Threats in Southern Zambia: A Land Tenure Dimension** 54
- MONA BARTLING, CHRISTIAN BUNN, FABIO CASTRO, HENRIETTE WALZ:  
**Identification of Suitable Tea Growing Areas in Malawi under Climate Change Scenarios** 55

<b>BIBIANA BETANCUR CORREDOR, JUAN CARLOS LOAIZA USUGA, MANFRED DENICH, CHRISTIAN BORGEMEISTER: Site-Specific Management Approach for Reclamation of Alluvial Gold-Mining Waste Deposits with Agroforestry Systems in Colombia</b>	56
<b>VIRGINIA RODRIGUEZ GARCIA, PATRICK MEYFROIDT, FRÉDÉRIC GASPART: Linking Land Use Displacement, Agricultural Intensification and Forest Transitions – A Contribution to Theory Development in Land System Science</b>	57
<b>YASMINA ADEBI, JOACHIM VOGT, LAURENT G. HOUESSO, BRICE A. SINSIN: Assessing the Impact of Porto Novo Lagoon Utilisation and its Sustainable Management in Benin Republic</b>	58
<b>MICHAEL ELIAS, UWE RICHTER, CHRISTIAN HÜLSEBUSCH, OLIVER WASONGA, RICHARD Y. M. KANGALAWÉ: Examining Land Use and Cover Change Along the Great Ruaha River Catchments in Southern Tanzania with Remote Sensing and GIS Techniques: 1986 – 2015</b>	59
<b>ANDREW CHILOMBO, DAN VAN DER HORST, CASEY RYAN: Optimism and Populism of Land Acquisitions: A Case Study of Nansanga Farm Block in Zambia</b>	60
<b>ACHILLE JEAN JAZA FOLEFACK, DIETRICH DARR, MARIE GAELLE NGO NJIKI: Safeguarding the Ngwei Forest Areas (Cameroon) by Increased Oil Palm Productivity and Production Factors</b>	61
<b>TILL MONTAG, PHILIP BECKSCHÄFER, CHRISTOPH KLEINN: Assessing Phenological Patterns of Rubber Tree Plantations (<i>Hevea brasiliensis</i>) in Xishuangbanna with Landsat Satellite Imagery</b>	62
<b>TIPHAINE LEUZINGER, DOMINIC BLAETTLER, AQILA HAIDERY, PIA FEHLE: Livelihoods and Sustainable Land Management in the Mountainous North of Afghanistan</b>	63
<b>GOHAR GHAZARYAN, OLENA DUBOVYK, FABIAN LÖW, NATALIJA KUSSUL, JÜRGEN SCHELLBERG: Crop Type and Condition Monitoring: A Multi-Temporal and Multi-Sensor Approach</b>	64
<b>MARCOS JIMÉNEZ-MARTÍNEZ, FRANCIS MOLUA MWAMBO, CHRISTINE FÜRST: Alternative Landscapes to Face Land and Energy Scarcity: Case Study in Sudanian Savannah of Ghana</b>	65

ROMAN SELIGER, DIETMAR SATTLER, ANTONIO SOARES DA SILVA, HELGA RESTUM HISSA, JÜRGEN HEINRICH: <b>Status, Drivers and Management of Degraded Sloped Pastures in the State of Rio de Janeiro</b>	66
CHANTAL INGABIRE, PATIENCE MSHENGA, CHRISTINE BIGLER, MICHÈLE AMACKER, ELIUD BIRACHI: <b>Shifting from Subsistence Farming in Rwanda: Understanding the Effects on Food Access among Smallholder Farmers</b>	67

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## Remote Sensing Based Mapping of Crop Rotation Systems in the Sudanian Savannah of West Africa

MICHAEL THIEL, ALEJANDRA NARVAEZ VALLEJO, GERALD FORKOUR,  
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West Africa is well known as a region with a very high poverty rate and high population growth. The region is also known to be highly vulnerable to climate change. Agriculture still is a main source of income in the Sudanian Savannah Zone of West Africa where about 60–80% of the population lives from subsistence farming. Major crops in the study region, composed of watersheds in Ghana, Burkina Faso and Benin, are cereals such as sorghum, millet, maize and rice. Cotton is widely grown as a cash crop. In the past, farmers practised rotational farming including fallow periods of about three to five years. Suitable land for farming becomes rare due to land degradation and population growth. Consequently, fallow periods decreased or agricultural areas are constantly used with negative effects on soil fertility and yields. Crop rotation and intercropping, the latter defined as the growth of different crops on the same field, are known as adaptation strategies to land pressure and yield insecurity. However, the spatial distribution and appearance of these cropping systems is unknown in the region. Remote Sensing provides the data and methodological framework to derive such information. We mapped land use / land cover on 5 m geometric resolution during three consecutive years from 2013–2015 using a multi-sensor, multi-temporal non-parametric classification scheme. The classification includes crop types on a field base and covers three watersheds within the region. Since Remote Sensing mapping is always accompanied by errors, this study focuses on the analysis to which extend the combination of maps of the three consecutive years allow the delineation of crop-rotation systems. Therefore, we applied post-classification change detection on pixel and field base and compared the results with ground-truth survey and questionnaire data. Results showed that crop rotations could be mapped with an accuracy of 60 – 77 %. Crop rotations can be found throughout the area, while the huge number of intercropped fields hinder the detection of the crop rotations especially close to settlements.

**Keywords:** Crop rotation systems, multi-sensor, remote sensing, West Africa

## **Changes in Local Land Tenure System in Response to Swidden Transformation in Southern Chin State, Myanmar**

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Swidden cultivation has been one of the most common land use systems in the upland regions of the tropics. Many researchers agreed that swidden cultivation is still an important practice for the livelihood of upland communities, providing local resilience in the face of turbulent social and ecological changes. Moreover, swidden farmers have been practicing unique customary land management systems that preserve cultural identity, equitable and secure land tenure, and social mechanisms that enhance community resilience. However, due to the increased access to market, the new cash crops were introduced and swidden farmers have transformed their traditional shifting cultivation practices towards permanent agriculture. To understand the impact of swidden transformation on local land tenure system, this study took 12 case study villages located in and around Natma Taung National Park, southern Chin state of Myanmar. The study applied Ostrom's eight governance principles to analyse customary land tenure system of swidden farmers. A total of 150 households were randomly selected to analyse household livelihood strategies and their compliance with local customary practices. Hierarchical cluster analysis was applied to categorise households based on their income from different livelihood sources. Cultural consensus analysis was later applied to determine household's compliance with local customary land management practices. The results demonstrate that households that engaged more in permanent agricultural practices are less compliant with local customary practices. Moreover, local land tenure systems have changed from collective to individual ownership in response to the introduction of new cash crop namely elephant foot yam. This particular trend has negative impact on the livelihood of marginalised and landless households who previously have access to land under the communal land tenure system. The study suggests that legalising communal land tenure system may reduce negative impacts on the marginalised households and may increase social equity and community resilience against turbulent social and ecological changes.

**Keywords:** Customary land tenure, rural livelihoods, swidden transformation

## Nested Archetypes of Vulnerability in African Drylands: Where Lies Potential for Sustainable Agricultural Intensification?

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Food production is key to achieving food security in the drylands of sub-Saharan Africa. Since agricultural productivity is limited, however, due to inherent agro-ecological constraints and land degradation, sustainable agricultural intensification has been widely discussed as an opportunity for improving food security and reducing vulnerability. Yet vulnerability determinants are distributed heterogeneously in these drylands and sustainable intensification cannot be achieved everywhere in cost-effective and efficient ways. To better understand the heterogeneity of farming systems' vulnerability in order to support decision making at regional scales, we present archetypes, i.e. socio-ecological patterns, of farming systems' vulnerability in the drylands of sub-Saharan Africa and reveal their nestedness. We quantitatively indicated the most relevant farming systems' properties at a sub-national resolution. These factors included water availability, agro-ecological potential, erosion sensitivity, population pressure, urbanisation, remoteness, governance, income and undernourishment. Cluster analysis revealed eight broad archetypes of vulnerability across all drylands of sub-Saharan Africa. The broad archetype representing better governance and highest remoteness encompassed the largest area share (19%), mainly indicated in western Africa. Moreover, six nested archetypes were identified within those regions with better agropotential and prevalent agricultural livelihoods. Among these patterns, the nested archetype depicting regions with highest erosion sensitivity, severe undernourishment and lower agropotential represented the largest population (30 %) and area (28 %) share, mainly found in the Sahel region. The nested archetype indicating medium undernourishment, better governance and lowest erosion sensitivity showed particular potential for sustainable agricultural intensification, mainly in western and some parts of southeastern and eastern Africa. Insights into the nestedness of archetypes allowed a more differentiated discussion of vulnerability and sustainable intensification opportunities, enhancing the evaluation of key interlinkages between land management and food security. The archetypes may support the transfer of successful intensification strategies based on similarities among the drylands in sub-Saharan Africa.

**Keywords:** Archetype, dryland, nestedness, pattern, socio-ecological

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## Identifying Tipping Points in the Supply of Ecosystem Services in Rural Environments of South-East Asia

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The expansion of large-scale plantations has a major impact on tropical and subtropical landscapes, and in turn on their inhabitants. Especially in rural south-east Asian regions, characterised by agriculture and forestry, people are highly dependent on the supply of ecosystem services (ESS) and the preservation of ecosystem functions (ESF) in order to maintain their livelihoods in the long term. The assessment of ESS has considerably gained momentum concerning both scientific studies, but also political decision making processes. We use the ESS concept to analyse the impact of potential future land use trends on a wider range of interdisciplinary topics. In this context, we introduce a methodology for incorporating multidisciplinary modelling and statistical analysis in order to identify tipping points in the provisioning of ESS. The tipping point analysis includes hydrological, agronomical and climate-regulation services, as well as multiple facets of biodiversity. The evaluation of temporal trajectories in the provisioning of ESS and their potential tipping points allows us to estimate Safe Operating Spaces (SOS) within our example dataset. The geographical focus of this dataset is the Naban River Watershed National Nature Reserve (NRWNNR) in the Xishuangbanna prefecture, Yunnan province, PR China. By combining multiple SOS, according to each of the modelled ESS, we define a framework of multi-topical Safe Operating Spaces. Structured approaches for the integration of transdisciplinary aspects into assessments are currently not well adapted to the needs and abilities of interdisciplinary modelling. The development and field testing of such a methodological framework for information transfer from stakeholders to science and *vice versa* is therefore an integrated part of this study. We offer researchers a tool to analyse potential critical thresholds and assess the socio-ecological resilience related to land use change, both *ex-ante* and *ex-post*. Our results contribute to an improved understanding on how to identify, evaluate and communicate the effects that human interventions have on the provisioning of ESS/ESF in the analysed systems considering questions of scale, modelling bias, resilience and off-site effects.

**Keywords:** Ecosystem services, environmental thresholds, safe operating space, socio-ecological resilience, tipping points

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## Farming Inside a National Park – What Is the Way Forward?

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Bwabwata National Park is among the few protected areas in Africa where people are permitted to reside inside the Park. However, the strict regulations on resource use created a challenging food environment for the local indigenous previously hunter-gatherer San people. Due to the daily struggle with food-insecurity, farming plays an increasingly important social and cultural role among these communities. The aim of this study is to investigate whether and how present farming practices inside the NP can support food security and conservation aims simultaneously.

Between March and May 2017 in-depth interviews were carried out with 50 farmers across 5 villages to understand the local characteristics of past and present farming practices, the available inputs and the gained crop yield. Semi-structured interviews with governmental officers, NGO representatives and conservation and agriculture experts were also undertaken. The interviews were analysed by qualitative content analysis, and GPS mapping and harvesting surveys were carried out to supplement the qualitative data.

The results show that food security is not being met with present farming practices. Crop yields are generally low and support the families of the farmers for only 3–4 months a year at most. Conservation efforts are also challenged by the current ‘slash and burn’ practices as farmers frequently shift their crop production areas due to soil erosion and human-wildlife conflicts. Local farmers lack the means and knowledge to undertake soil management and protect their crops from pest and wildlife damage. Stakeholders involved in the management of the NP have conflicting and minimal interactions with each other and with the local farmers. Meanwhile, experts with local knowledge are proposing new approaches towards local food security in the NP. We identify these conflicts and contradictions, and present possible solutions and pathways forward for both local food security and conservation in the park.

**Keywords:** Conservation, farming, food security, indigenous peoples, national park

## Climate Vulnerability Assessment and Sensitivity Analysis in Rainfed Farming Communities of Kerala, India

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Smallholder farmers, over 1.5 billion people worldwide, are disproportionately vulnerable to the impacts of climate change as a result of poverty, reliance on natural resources and limited capacity to adopt new livelihood strategies. For them, climate change is a daily reality that threatens their source of livelihood: agriculture. In India, more than fifty percent of farmers rely on rainfed agriculture in which ‘delayed, deficient or erratic rains’ lead to severe decline in production and productivity. There is, therefore, an urgent need to identify approaches that strengthen the adaptive capacity of smallholders. Here comes the importance of Watershed Development Programmes (WDPs) as they have the potential to make a significant contribution to enhance the resilience of rain-fed farmers through natural resource management and livelihood support system activities. The Government of India initiated WDPs for rainfed areas more than five decades ago and doubled the financial support for every five year plan. Therefore, it is of great importance to exercise a closer scrutiny over the WDPs, especially in the light of growing concerns about climate change.

In this context, our study analyses and compares the effectiveness of the WDPs against climate vulnerability in one of the most vulnerable hotspots in Kerala, India. For this, we deduced a Climate Vulnerability Index (CVI), which comprises of three vulnerability dimensions, ten major components that describe the dimensions and 59 individual indicators for the assessment of the major components. The primary data used for this study were obtained from household surveys and key informant interviews. We used a bootstrapping method and conducted a sensitivity analysis to test the performance of the CVI among three different communities. First, there are no significant differences in the adaptive capacity between the communities, i.e. the CVIs are similar. However, we found significant differences in sensitivity and exposure dimensions. Secondly, the sensitivity analysis shows that ‘Livelihood Strategies’ and ‘Social Network’ are the most influencing major components of vulnerability in the watersheds. The bootstrapping approach proved to be very helpful in testing for the robustness of our results and is replicable to evaluate the potential effectiveness of various other climate change programmes.

**Keywords:** Adaptive capacity, bootstrapping, climate vulnerability, sensitivity analysis

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## **Land Conservation and Food Security Threats in Southern Zambia: A Land Tenure Dimension**

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In Zambia, smallholder farmers are the major food producers and highly dependent on rain fed agriculture. Amidst the environmental challenges, sustainable land practices are imperative to attaining better agricultural productivity and food security status. The objectives of this study are to quantify the differential impacts of land tenure regimes on incidence of land practices in agricultural productivity, to establish the prevalence of food insecurity using the food consumption score indicator and to determine factors that influence food security. Data collection employed a structured questionnaire survey and focus group discussions on land tenure systems existing in Zambia namely state (leasehold) and customary (indigenous) covering 400 farm households in four districts of southern Zambia. Data analysis was done in IBM SPSS and STATA software with multiple regression analysis and ordered probit model statistical methods. The results showed that land practices measured as adopting levels was significant in state land with activities of crop diversification, fertiliser tree planting and use of organic manure. Similarly, food security status revealed better results for state land compared to customary land with 40 % and 68 % poor status indicating significant statistical differences. The factors that significantly contributed were age, education, marital status, household size, access to credit, number of crops, number of livestock species and household income. The study suggests that implementation of sustainable land practices play a vital role in improvement of agricultural productivity and food security status. In addition, land tenure systems have a huge influence in investments of land conservation and this calls for concrete supportive land and agricultural policies.

**Keywords:** Adopting, food security, land tenure, practices, Zambia

## Identification of Suitable Tea Growing Areas in Malawi under Climate Change Scenarios

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Food security in Malawi is extremely vulnerable to climate change; a situation which is exacerbated by widespread poverty. Variation in climate and weather events such as precipitation, droughts and floods impact the growth rate and quality of the tea plant. In this study we discuss possible climate change impacts on the tea production of Malawi. In recent years a shift has been observed in the climatic conditions of the country. From 1960 to 2003 the average temperature increased by 0.9°C and a higher number of hot days and nights were recorded. These changes may have a strong impact on the tea plant in terms of growth and quality and therefore on the tea production. It is projected that precipitation rates in the future are defined by a strong heterogeneity and more frequent extreme weather events are expected such as heavy rainfalls or droughts. Using global change models (GCM) we assessed climate change impacts and projected risks to tea production in Malawi. Suitability types for tea production were defined by RandomForest (RF) classification using a combination of spatial climate data from WorldClim and a database of occurrences of tea production. Malawian experts evaluated and verified tea occurrence data for model input and confirmed the validity of the resulting model for current conditions. The validated models were then extrapolated on climate data for the periods 2020 to 2049 and 2040 to 2069 in an intermediate emissions scenario for 19 GCMs. The models estimate an overall loss of suitable area for tea in the future. We focused on the districts Mulanje, Thyolo and Nkhata Bay. Only Mulanje is able to cope with the climate change. Thyolo, as well as Nkhata Bay, will experience a drastic reduction of suitable area. As a conclusion, it is highly recommended to implement adaption strategies in the districts most effected by climate change.

**Keywords:** Climate change, impacts, Malawi, random forest, suitability, tea



## Site-Specific Management Approach for Reclamation of Alluvial Gold-Mining Waste Deposits with Agroforestry Systems in Colombia

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Alluvial gold mining activities generate large amounts of dredged sediments that are deposited in banks and areas near the river. Agroforestry systems have been established for reclamation of these deposits in the gold mining area of El Bagre, Colombia, with the aim to support agricultural land use by establishing crops in more fertile areas of the deposits while bringing non-fertile areas to productivity through the planting of trees. Spatial variability of sediment deposits depends on the type of machinery used for mining and geochemical properties of the exploited alluvial areas.

To support farmer's decision making regarding soil management, the main objective of this study was to understand the spatial variability of the soil properties of the deposit areas that might affect plant growth and crop productivity. For this purpose, site-specific management zones were delineated to identify areas within the field with homogeneous properties. Delineation of management zones allowed to identify areas within the field with homogeneous characteristics such as texture and nutrient levels. Soil samples were taken from 310 locations distributed in four reclamation areas of 50 ha each, established in 2002, 2006, 2010 and 2014. Spatial distribution of soil properties was generated through spatial interpolation with ordinary kriging. Spatial principal component analysis and fuzzy cluster classification were performed to delineate management zones. For validation of the management zones, multispectral aerial images were used. NDVI maps were elaborated with the multispectral orthomosaics and integrated with ground-based measurements of physicochemical soil properties. This integrated analysis can be used to direct site-specific management for the ongoing reclamation process by identifying areas with high potential for crop establishment and areas that should be revegetated with trees or cover crops to improve soil quality. Combined analysis of NDVI maps and physicochemical properties of each area allowed to classify the studied areas in four management zones. The presence or absence of vegetation cover within these areas was related to differences in organic matter, nutrients content and particle size distribution of the soil. These results suggest that the delineated management zones can help to identify management strategies and inputs required to improve crop productivity and revegetation.

**Keywords:** Aerial image, geostatistics, reclamation, spatial variability

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## Linking Land Use Displacement, Agricultural Intensification and Forest Transitions – A Contribution to Theory Development in Land System Science

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Land constitutes a nexus between the current environmental and societal challenges. Balancing these tradeoffs and synergies is the focus of Land System Science (LSS). Within this frame, we analysed the three central issues of contemporary land systems: land use displacement, forest transitions and agricultural intensification. We started by establishing a set of operationalizable hypotheses and causal mechanisms based on different theories addressing those topics (environmental Kuznets curve, ecological modernisation, comparative advantage, pollution haven, theories on forest transition among others). LSS has contributed to understand the causes and consequences of land change through the production of methodological innovations, empirical observations and contextual explanations to land changes, in particular through case studies. However, very little theoretical development has taken place in this discipline. Theories intended to explain these three types of land changes leave important aspects unexplained and theory addressing the linkages between their dynamics is not convincing. Models in land changes also suffer from this, as they are often based on practical rather than theoretical considerations. In addition, the important role of trade because of globalisation is sometimes not properly taken into account; current geographic and economic theories focus either on international trade or on local land change processes but they rarely link the two. The methodology of this paper consists on a review of different theories that deal with land changes and the identification of the hypothesis and causal mechanisms in which they are based. Followed by the operationalisation of those hypotheses and their analysis using panel data econometrics. The panel is composed by a sample of 200 countries, which have been classified into smaller and more homogenous groups. With that propose socioeconomic data (from World Bank, ILO, World Development Indicators), trade data (from United Nations COMTRADE, FAOSTAT), biophysical variables (from FAOSTAT) and variables on consumers attitudes has been used. The results obtained from the econometric analysis are expected to fix the current gap of LSS in theory development and move forward a new generation of LSS. At the same time, this information will serve policy makers when making decisions on land management at global and local scales.

**Keywords:** Agricultural intensification, forest transitions, land system sciences, land use displacement, trade

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## Assessing the Impact of Porto Novo Lagoon Utilisation and its Sustainable Management in Benin Republic

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The lagoon of Porto-Novo is one of the most important ecosystems in Benin because of its ecological function for aquatic animals and its socio-economic services for surrounding population. Over the past years, the use of natural resources of the lagoon was intensified generating social conflicts and natural ecosystem degradation. Through this study, we firstly aim to analyse the forms and the intensity of water uses at Porto Novo lagoon with regards to its regenerative capacity and secondly to assess the consequences of the use of the lagoon and the resulting risks on the surrounding population. Socio-economic survey was conducted in 7 villages surrounding the lagoon to assess the lagoon uses form and its consequences on both the ecosystem and local population. Our results showed that the lagoon of Porto-Novo is used for fishing, sand extraction, transportation of goods and services, as well as domestic uses. Fishing is the main developed activity in and around the lagoon. The analysis of the regenerative capacity of the lagoon as well as its current productivity trends indicated a real depletion and threat on fish stocks in the lagoon. Thus, a sustainable management of the lagoon is required through an integrated approach which takes into account the structure and dynamics of fish productivity as well as the involvement of local population and different stakeholders for an effective management and sustainable use of the lagoon resources. Finally, this study provides useful information for policy makers to promote the sustainable management of the lagoon of Porto-Novo in Benin and reversing the process of overuse.

**Keywords:** Degradation, ecosystem, lagoon of Porto-Novo, regenerative capacity, sustainable management

## Examining Land Use and Cover Change Along the Great Ruaha River Catchments in Southern Tanzania with Remote Sensing and GIS Techniques: 1986 – 2015

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The Great Ruaha River flows from Mbeya through Njombe and Iringa regions in the Southern Highlands of Tanzania and connects to Kilombero and Rufiji Rivers in Morogoro and Coast regions, respectively. The River and its catchments form Kilombero wetland, which is a potential ecosystem to the Tanzania's economy. However, the intense utilisation of land resources for various human activities has resulted into some changes in the land cover type along the river basin and its catchments. To analyse the spatial-temporal changes, multispectral LANDSAT imageries of 1986 and 2015 time periods were used. A total of seven land cover types were identified and classified and later change detection analysis was performed. The dynamic index of land use and land cover was computed to quantitatively monitor the change in intensity of one land cover type. Over the period under study farming activities along the river catchments increased by 27 %, with a dynamic degree of 0.2541 percent. On other land cover types, forest, bushland and grassland decreased by 27 %, 24 % and 11 %, with dynamic degree of (-0.0501), (-0.3633), and (-0.7848) percentages respectively. It was detected that wetlands increased by 7 %, with a dynamic degree of (5.9813) percent. The land cover change detected contributing to depletion of natural vegetation, which may cause changes in the water balance in the river and its catchments. The study highlights the need for a management plan for enhancing the sustainable conservation of the Great Ruaha River, considering the human activities, climatic anomalies and hydrological conditions of the River basin and its catchments.

**Keywords:** Farming expansion, Ruaha River catchments, Tanzania, vegetation loss

## **Optimism and Populism of Land Acquisitions: A Case Study of Nansanga Farm Block in Zambia**

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The contemporary phenomenon of large scale land acquisitions (LSLAs) for food security, financial investments, biofuel production and carbon markets, have spurred polarised debates among development practitioners, policy makers, civil society organisations, business communities and local communities. The debates are bifurcated into techno-economic optimism on the one hand, and naively grounded and unsubstantiated populism, on the other. Literature on LSLA is more grounded at global, continental/regional and national levels. These levels of investigation have focussed on land global markets, global financial uncertainties, biofuels and the spike in food prices of 2007/2008. The investigations take a geopolitical lens that categorises the global north as ‘resource poor, financial haves’ and the global south as ‘resource rich, financial have-nots.’ They have also focused on national policies, corruption and government complicity. The analyses at these levels share a common caveat: reliability of data. The actual socio-economic and ecological implications at community level are not fully understood. This is owing to the incipience of the phenomenon, and epistemological and methodological challenges. In 2002 the Zambian government approved the establishment of farm blocks across the country to commercialise agricultural land to attain economic diversification, enhance food security, open up undeveloped rural areas, reduce poverty and minimise rural to urban migration. In the LSLAs debate, where does the Zambian farm block programme as model of rural development fit? Taking Nansanga farm block in central Zambia as case study, this research seeks to challenge the mainstream socio-economic and ecological optimists and populists in the LSLA debates. The research uses participatory rural appraisal methods. Preliminary results indicate that socio-economic and ecological implications of LSLA are diverse and context-specific. They indicate that there have been improvements in physical capital and cash flow into Nansanga area on the one hand, and on the other, land loss, poor wages and land use change.

**Keywords:** Large scale land acquisitions, livelihoods, Nansanga farm block, Zambia

## Safeguarding the Ngwei Forest Areas (Cameroon) by Increased Oil Palm Productivity and Production Factors

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Due to increased world demand for palm oil and suitable conditions for oil palm production, Cameroon has witnessed a sharp rise in oil palm plantations since 2009. Unfortunately, their expansion represents a threat to forest landscapes, wildlife biodiversity and the environment and contributes to deforestation and degradation of natural forests. Hence, this study aims to model the most convenient economic and environmental alternative to smallholder farmers willing to conserve the forest while simultaneously producing oil palm so as to earn high returns. The study uses secondary and primary data collected from April to September 2016 in the Ngwei forest areas of Cameroon, where 216 smallholder farmers were randomly selected in the Makondo and Ndjockloubé villages. Data on input and output levels as well as prices of oil palm and forest products were analysed using a Linear Programming (LP) technique to compute the number of hectares of land to be allocated to the forest and/or oil palm activities so as to maximise the social welfare, given the constraints of available resources of land, labour, capital and oil palm trees. From the field survey results, a smallholder farmer uses on average 15 ha of land, 8760 mandays of labour, 880250 FCFA of capital, and 1429 oil palm plants per cropping season. The preliminary LP results suggest that a socially efficient outcome is achieved when smallholder farmers use 9.993 ha of land (67 % of land availability) for oil palm cultivation and 5.007 ha (33 % of land availability) for forest conservation. The sensitivity LP analysis, however, suggests that, a higher proportion of forest land could be conserved if smallholder farmers were encouraged and supported to increase the productivity of their plantations through the offer of improved seed varieties, good farm maintenance or mechanisation, farm technology innovation, and improved farming conditions. The government policy should support such economically and environmentally more sustainable solutions, which enable smallholder farmers to earn similar or higher returns while preserving the environment.

**Keywords:** Forest, linear programming, oil palm, smallholder farmer

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## Assessing Phenological Patterns of Rubber Tree Plantations (*Hevea brasiliensis*) in Xishuangbanna with Landsat Satellite Imagery

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The timing of phenological events of trees, such as leaf onset and senescence, has essential implications for hydrological and biogeochemical cycles as well as for organisms, populations and ecological communities. For rubber trees in Xishuangbanna, Yunnan, China, it is assumed that the timing of the leaf onset is related to the trees' susceptibility to powdery mildew disease, a disease caused by the fungus *Oidium heveae* that predominantly infests young and tender leaves after sprouting. Leaves and twigs of infested trees die-back affecting photosynthetic efficiency, and hence, reducing seed and latex production. There are indications that late wintering trees, i.e. trees which regrow leaves at a later point in time, are particularly affected by the disease. Therefore, information on the timing of the leaf onset is crucial for the scheduling of disease control including sulfur fumigation. In the context of monitoring and assessing plant phenology, ground-level surveys are very time consuming and expensive so that remote sensing techniques may be employed for indirect observations. This study describes the possibilities and limitations of using Landsat satellite imagery with a temporal resolution of 16 days and a pixel size of 30 m to model and investigate the temporal and spatial variability of phenological events across China's second largest rubber growing region – Xishuangbanna. We used Landsat time series data from 1991, 1995, 2003, 2014, 2015 and 2016 to map phenological patterns of rubber plantations and analysed relationships between the timing of phenological events and topographic variables. Analyses revealed that the timing is among other factors influenced by the geographic location and, at a finer scale, by the topographic position of the rubber plantation. Earlier leaf onset was observed on upslope positions and at higher elevations. The described relationships between leaf onset and topography provide meaningful information to predict the timing of leaf onset of future years and to support a more focused control of the powdery mildew disease in rubber plantations.

**Keywords:** Landsat, leaf onset, phenology, Xishuangbanna

## Livelihoods and Sustainable Land Management in the Mountainous North of Afghanistan

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Life in the mountainous North of Afghanistan is exceptionally harsh. In a context of high fragility, deep poverty and severe land degradation questions to do with food security and livelihoods figure very prominently. Experiences from different parts of the world show that sustainable land management (SLM) practices may constitute a promising way forward. This study investigates people's livelihoods in a case study area in Northern Afghanistan. Based on that, it identifies potentials and limitations for the implementation of SLM practices that were recently introduced by a development project (terracing, gully treatment, pasture rehabilitation, grazing plan etc.). For this purpose, a survey was conducted in three villages with 121 women and men farmers, complemented with 24 key informant interviews and 26 focus group discussions. The analysis focuses on peoples' perceptions and whether and how these differ by gender, age, socio-economic position and village context. Findings suggest that agriculture is an important but not the only livelihood activity of local people. Local off-farm activities such as craft, small-scale trade, gold washing, and agricultural wage labour as well as labour migration to other villages, districts or countries (i.e. Iran) also play a crucial role. Especially part of the young generation aspires to new livelihoods and to an urban life. Many people mentioned conflicts, physical and mental illnesses and disabilities, a lack of resources and debts as major challenges. In addition, external constraints such as insecurity, lack of employment opportunities and missing infrastructure, schooling and health services were mentioned. All of the above absorbs attention, workforce and money and seems to have implications on the diffusion of the newly introduced SLM practices: while people appreciate the project interventions and observe positive results, spontaneous replication is low or even absent. Potential hindering factors mentioned by farmers regarding the practices include high establishment and maintenance costs, heavy workload, required skills and coordination efforts. From the current perspective, external support seems thus to be necessary for the implementation of SLM practices at a larger scale. The manifold needs and aspirations of local people moreover suggest that further issues within and beyond agriculture require utmost attention.

**Keywords:** Adoption of innovation, fragility, migration, rural development, socio-economic research

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## Crop Type and Condition Monitoring: A Multi-Temporal and Multi-Sensor Approach

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Due to growing population, sparse land and water resources, the need for enhancing agricultural productivity to ensure food security is increasing. Accurate crop maps and other data products derived from earth observation can build the basis for agricultural monitoring at different ranges of scale. Such data are one of the essential means to support sustainable land management. In this study, we exploited the intra-annual temporal signatures of remotely sensed observations and used the prior knowledge of crop calendars to create a sequential processing chain for crop classification and condition monitoring by focusing on drought impact. Time series observations that were derived from both optical (Landsat-8, Sentinel-2) and Synthetic aperture radar (SAR) sensors, were used in order to identify the crop type and productivity reduction due to moisture scarcity or increased evaporative demand. Landsat-based time-series metrics that capture the within season phenological variations were preprocessed and analysed using Google Earth Engine cloud computing platform. The development stage of each crop throughout the growing season was modeled and the model's output was further used for the automatic generation of training samples. Sentinel-1 images were used as additional input of contextual feature information to classification. Two classification schemes were applied (Random forest and decision fusion) to discriminate the main crops in the study area: cereals (wheat, barley), maize, soy, and sunflower. The Normalized Difference Vegetation Index (NDVI) and dual (VV + VH) polarisation backscattering time series were used to identify the main characteristics of drought (start, end, duration, intensity) for different crops during different stages of the crop development. Tested methods yielded acceptable levels of accuracies in the range of 80–86%. Combined use of the Landsat time series and Sentinel-1 data improved the classification accuracy. These sensors offer imagery with 10–20 m to 30 m spatial resolution, providing opportunities for regional monitoring of crop conditions. The methods were tested on data from two consecutive years, which enabled us to study the effect of inter-annual meteorological differences. Based on our results, we recommend the use of multimodal satellite data to derive accurate crop maps and information on crop condition over several years.

**Keywords:** Crop mapping, drought hazard monitoring, Landsat, random forest, Sentinel-1

## Alternative Landscapes to Face Land and Energy Scarcity: Case Study in Sudanian Savannah of Ghana

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Despite steady economic growth, sub-Saharan Africa faces major challenges to develop its bio-economies due to stagnating or even decreasing efficiency in the conversion of environmental resources into socio-economic goods. Many regions of the continent experienced no improvement in terms of nutrition security and hunger alleviation over the last 20 years. There is potential to raise yields significantly but the commercial balance of most African countries hardly allows to undertake the required measures. Therefore, we hypothesise that the path of development followed in the biomass production sector has been so far unsustainable. We propose to concentrate efforts on changes in landscape configuration to maximise the benefits obtained from the potential of nature to sustain biomass provision. We simulated data for each of the main agricultural and woody land use types of the interior savannahs of West Africa under different management techniques, on their capacity to provide biomass products and maintaining ecosystem functions, complemented by a holistic energy balance assessment that includes human and animal labour inputs, as a key measure of sustainability. The results have been stored in the database of a land use change model used to create different landscape scenarios over a fine-resolution land use map. The potential of the current land use pattern to satisfy present human calorie intake requirements is sufficient, but some micro-nutrient shortages are found, particularly acute in the case of vitamins. Future demands of calorie intake will most likely be attained by further agricultural expansion, which will imply a reduction of vegetation cover, including clearing of woodlands to satisfy fuel demands. No alternative land use pattern will provide nutritious enough food unless significant improvements in the irrigation systems are achieved. The potential of promising crops, such as maize, to enhance food and nutrition security is limited, unless mineral fertiliser application increases 5- up to 10-fold beyond current levels, due to their poor performance on the available (low) fertile lands. Furthermore, a trade-off exists between increasing rainfed agriculture yields to desirable levels and water available for irrigation. We provide recommendations regarding cropping systems that enhance the sustainable production of food and fuel.

**Keywords:** Data envelopment analysis, energy, trade off analysis

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## Status, Drivers and Management of Degraded Sloped Pastures in the State of Rio de Janeiro

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Large areas of the Atlantic Forest region in the state of Rio de Janeiro (RJ), Brazil, have suffered from historical deforestation and degradation due to landscape transformation towards economically unsustainable coffee and sugar cane plantations converted into cattle pastures afterwards. Today, over 50% of the RJ area is covered by pastures mainly on slopes and managed by smallholder farmers. An inadequate, lacking or unsustainable management in combination with unsuitable environmental conditions has led to high pasture degradation, threatening the socio-ecological resilience of the landscape. If no appropriated rehabilitation measures and/or sustainable pasture management will be applied to this fragile, historically strongly modified landscape, pastures will soon devastate to a degree and extent, where land use will not be profitable anymore and the rural population may lose its main source of income. The study aims at improving the adaptation to exacerbating environmental conditions in rural areas of RJ, driven by inappropriate land use and climate change with increased droughts and heavy rainfalls. The status and drivers of pasture degradation are analysed based on a case study in the municipality of Itaocara (RJ) and linked to possible strategies for pasture rehabilitation and appropriated management. The implementation, monitoring and post-management of a low-cost pilot rehabilitation measure on a medium degraded sloped pasture in rural Itaocara is presented which aims both at strengthening pasture resilience against degradation and continuation of extensive rotational pasture management at the same time. The selection of appropriated strategies depends on degradation level, site conditions, farmers' acceptance, expected costs, required man-power and time for measure implementation.

**Keywords:** Degradation, erosion, pasture rehabilitation, sloped pasture, unsustainable land-use

## Shifting from Subsistence Farming in Rwanda: Understanding the Effects on Food Access among Smallholder Farmers

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For over fifteen years, agricultural transformation strategies in Africa and specifically, Rwanda have focused on shifting from the largely subsistence to market oriented farming. This has been particularly taken as a key strategy to end poverty and food insecurity in the rural areas. As the majority of Rwandan farmers are smallholders, some concerns that the new production system may increase their vulnerability and risks to food insecurity have been raised. Although recent reports show that the level of food availability has increased in the country, farmers' dependency on food markets has also increased and surprisingly, cases of malnutrition still persist even in regions considered as the country's granary. The question is whether commercialisation of smallholder farmers would improve or worsen households' access to food and consequently affect their food and nutrition security. This paper used the Household Commercialisation Index (HCI) and the Household Food Insecurity Access Score (HFIAS) on a sample of 331 farmers to investigate the linkages between commercialisation and food security in Rwanda. Results showed that 32 % of the households could be categorised as market oriented famers. Regarding food access, the HFIAS calculations allowed us to classify 14 %, 18 % and 68 % households, respectively, as food secure, moderately food insecure and severely food insecure. Results of an Ordered Logistic regression showed that farmers with higher level of commercialisation were more likely to be food secure in terms of access. Other factors like land, access to credit, distance to market, and distance to the border (for cross-border trade) had a positive effect on the level of food security access. Male headed households were found to be more food secure.

**Keywords:** Commercialisation, food access, ordered logistic, Rwanda, smallholder



# Crop biotic stresses (DPG Session)

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## Invited Paper

- STEPHAN WINTER:  
**New Incursions of Pests and Diseases Present Serious Threats to Plant Health and Sustainable Agricultural Production in Sub-Saharan Africa** 72

## Oral Presentations

- JONAH NGENO, GEORGE CHEMINING'WA, ROBERT JACKSON, MARGARET HUTCHINSON:  
**Genetic Diversity and Phylogeny of Symbiotic and Endophytic Bacteria of Cowpea (*Vigna unguiculata*) in Seven Geographic Regions of Kenya** 73
- ADRIANE WENDLAND, STELLA CRISTINA DIAS VALDO, LEILA GARCÊS:  
**Systemic Infection and Aggressiveness of *Curtobacterium flaccumfaciens* pv. *flaccumfaciens* Analysed by Scanning Electron Microscopy in Different Genotypes of *Phaseolus vulgaris*** 74
- MURITHI HARUN, JAMES HAUDENSHIELD, FENTON DOUGLAS BEED, GEORGE MAHUKU, MATTHIEU JOOSTEN, GLEN L. HARTMAN:  
**Virulence Diversity of Soybean Rust Isolates from Africa** 75
- OLIVER CHITAMBO, SOLVEIG HAUKELAND, KOMI FIABOE, FLORIAN M. W. GRUNDLER:  
**African Nightshades and African Spinach Lures Plant Parasitic Nematodes to a Dead-End** 76

## Posters

- JOSEPH CUTLER, CHRISTIAN LÜCHAU, JULIANE LANGER, SUSANNE VON BARGEN, ORLANDO LOSADA ACOSTA, FÁNOR CASIERRA POSADA, ADRIANA CASTAÑEDA CÁRDENAS, MÓNICA BETANCOURT VAQUEZ, WILMER CUELLAR, EDUARDO ARVYDAS STASIUKYNAS, EMILIO AREVALO-PEÑARANDA, CARMEN BÜTTNER:  
**Development of a Certification Program for Virus-Tested Plant Material in Colombia: A Collaborative Initiative** 77

- CHRISTIAN LÜCHAU, JOSEPH CUTLER, JULIANE LANGER,  
SUSANNE VON BARGEN, CARMEN BÜTTNER:  
**Detection and Characterisation of a New *Ilarvirus* in *Passiflora edulis*** 79
- LISA MADER, LAURA ARMENGOT, THOMAS HILGER, MONIKA  
SCHNEIDER, JOACHIM MILZ, GEORG CADISCH:  
**Impact of Cocoa Cropping Systems and Varieties on Cherelle  
Wilt, Yield and Foliage Density** 80
- DJUIDEU TCHOUAMOU CHRISTIAN LANDRY, AMBELE CHABA  
FELICITAS, HERVE BISSELEUA:  
**Impact of Termites on Cocoa Yield under Different Cocoa  
Cultivation Systems in Cameroon** 81
- VIVIEN KRELL, DESIRÉE JAKOBS-SCHOENWANDT, STEFAN  
VIDAL, ANANT PATEL:  
**Improved *Metarhizium brunneum* Endophytism for Biological  
Protection of Potato Plants** 82
- MAME FATOUMATA GOUDIABY, IBRAHIMA SARR, MBACKÉ  
SEMBÈNE:  
**Efficacy of the Augmentative Release of *Bracon hebetor* against  
the Pearl Millet Ear Headminer** 83
- KATHARINA HERMANN, PASCAL HUMBERT, STEFAN VIDAL,  
MICHAEL PRZYKLENK, ELISA BEITZEN-HEINEKE, WILHELM  
BEITZEN-HEINEKE, ANANT PATEL:  
**The Project ATTRACAP: Optimisation of an Attract-and-  
Kill Strategy for Wireworm Control in Potato** 84
- LINDA MUSKAT, PASCAL HUMBERT, JÜRGEN GROSS, LOUISA  
GÖRG , CORNELIA DIPPPEL, ELISA BEITZEN-HEINEKE, WIL-  
HELM BEITZEN-HEINEKE, MICHAEL PRZYKLENK, ANANT  
PATEL:  
**The Project PICTA-KILL - Novel Strategies for Biological  
Psyllid Pest Control** 85
- ALEXANDER NIMO WIREDU, PATCHIMAPORN UDOMKUN,  
FLEMMING NIELSEN, BERNARD VANLAUWE, RANAJIT BAN-  
DYOPADHYAY:  
**Awareness and Perception about the Occurrence, Causes and  
Consequences of Aflatoxin Contamination and the Willing-  
ness to Pay of Aflatoxin Control in Burundi and Eastern Demo-  
cratic Republic of Congo** 86
- JULIET AKELLO, MWESHI MUKANGA, HENRY NJAPAU, JOSEPH  
ATEHNKENG, JOAO AUGUSTO, PETER COTTY, RANAJIT BAN-  
DYOPADHYAY:  
**Influence of Farming Systems on Aflatoxin Contamination of  
Groundnut Crops under Field Conditions in Zambia** 87

---

DOROTHEA LINK, NAJIM TOUHAMI, ROLF GEISEN, MARKUS SCHMIDT-HEYDT, HANS-GEORG WALTE, CHARLES NKONGE, MARYGORETTI GACHAGUA, STEVE MUCHIRI, CHRISTINE SCHWAKE-ANDUSCHUS: <b>Networking on Aflatoxin Reduction in the Food Value Chain - AflaNet</b>	88
PATCHIMAPORN UDOMKUN, ALEXANDER NIMO WIREDU, CHARITY MUTEGLI, JOSEPH ATEHNKENG, MARCUS NAGLE, FLEMMING NIELSEN, JOACHIM MÜLLER, RANAJIT BANDY-OPADHYAY, BERNARD VANLAUWE: <b>Aflatoxin Distribution in Crop Products from Burundi and Eastern Democratic Republic of Congo</b>	89
LILIAN NKENGLA, HOLGER KIRSCHT, SURESH BABU, NAMITA PAUL, LAVA KUMAR, RACHID HANNA, DEBORAH OLAOSEBIKAN, MARTINE ZANDJANAKOUT-TACHIN: <b>Assessing the Impact of Banana Bunchy Top Disease (BBTD) on Food Security Between Men and Women in Affected Communities in West and Central Africa</b>	90
LEA FORSTER, CARLOS CASTILLEJOS CRUZ, SALVADOR GARIBAY: <b>Ecofunctional Management Strategies for <i>Diaphorina citri</i> on Organic Orange Orchards</b>	91
EMMANUEL OLAJIDE, SOLVEIG HAUKELAND, WIM BERT: <b>Efficacy of Commercial and Non-Commercial Fungal Isolates for Suppression of Root-Knot Nematode on Pineapple</b>	92
SAID EL SALAMOUNY, MARTIN SHAPIRO, MERLE SHEPARD: <b>Plant Derived Oils as Ultraviolet Protectants for the Beet Armyworm Nucleopolyhedrovirus (SeNPV)</b>	93
ESMAT HEGAZI, CORNEL ADLER, WEDAD E. KHAFAGI, ESSAM AGAMY: <b>Host-Preference and Parasitic Capacity of Five <i>Trichogramma</i> Species (Hym.: Trichogrammatidae) against some Stored Product Moth Pests</b>	94
ALLAN NDUWA MWEKE, SUNDAY EKESI, KOMI FIABOE, NGUYA KALEMBA MANIANIA, CHRISTIAN ULRICHS: <b>Performance of <i>Metarhizium anisopliae</i> (Metsch.) Sorok and <i>Beauveria bassiana</i> (Bals.) Vuill. Isolates against Cowpea Aphid (<i>Aphis craccivora</i> Koch) in Cowpea</b>	95

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## **New Incursions of Pests and Diseases Present Serious Threats to Plant Health and Sustainable Agricultural Production in Sub-Saharan Africa**

STEPHAN WINTER

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Pests and pathogens pose a significant threat to food production accounting globally for almost 20% of losses to agricultural production. While plant health threats from pests and diseases are as old as agriculture itself, a new dynamics has become evident by the enormous numbers of novel pathogenic organisms that are introduced often far from their original distribution into new areas, to spread and establish causing serious disturbances and imbalances in the management of crops. This dynamics is driven by a the sharp increase of global traffic including the exchange of materials across continents, a division of agricultural production and the intensification of agriculture per se. The changing climate presents additional stresses to crop cultivation from warming and unpredictable weather patterns with strong effects on the development of pest and pathogen populations, their dispersal and impact on both crops and environment. Plant health is compromised by all these negative effects which taken individually are difficult to quantify. However, as is evident from the recent outbreaks in particular in Africa; the devastating epidemics of bacterial wilt disease in banana, the spread of maize lethal yellowing virus disease, the range expansion and human assisted spread of cassava brown streak virus disease and the continent wide invasion of the fall armyworm *Spodoptera frugiperda*; most the biggest threats to agricultural production is from the incursion of NEW pests and diseases rather than from changes in pest & pathogen populations. Prediction and assessment of risks from emerging and re-emerging pests and pathogens is keeping research very busy while much less is done to support (resource-poor) farmers in taking the necessary preparatory steps to reduce impact.

**Keywords:** Biological invasions, climate change, pest risks

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## Genetic Diversity and Phylogeny of Symbiotic and Endophytic Bacteria of Cowpea (*Vigna unguiculata*) in Seven Geographic Regions of Kenya

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Cowpea is an important drought tolerant legume crop in Kenya. Its production is limited by nitrogen (N) deficiency in soils, but most farmers rely on organic manure and biological nitrogen fixation to supply nitrogen requirement of cowpea plants. *Bradyrhizobium* spp. USDA 3456 (Biofix) is the only commercial *Rhizobium* inoculant available for cowpea production in Kenya. However, research findings shows insignificant growth and yield response of cowpea inoculated with this strain of *Bradyrhizobium*, probably due to its low symbiotic efficiency. There is need therefore to identify and select native strains of cowpea rhizobia efficient in nitrogen fixation in Kenyan soils, but information on their genetic diversity is limited. The study objective was to characterise the genetic diversity of cowpea nodulating rhizobia in soils from 23 sites in seven geographic regions of Kenya, through sequencing and phylogenetic analyses of 16s rRNA and rec A genes.

Based on 16s RNA sequence analysis, 25 isolates were identical to known nitrogen fixing bacteria; twenty one belonged to genus *Rhizobium*, the rest were in genera *Bosea*, *Bradyrhizobium* and *Mesorhizobium*. There was congruence in phylogenetic grouping of rhizobial isolates in both 16s RNA and recA trees. However, incongruence in species identification of three isolates was observed in sequence analyses of both genes, but 16s RNA gene gave  $\geq 99\%$  sequence homology to known species in NCBI GenBank, and may have given better species identification. One isolate may represent a novel species in the genus *Rhizobium*. Forty three endophytic plant growth promoting bacteria were also isolated, and 84% were strains of *Bacillus megaterium* and *Bacillus aryabhatai*. Among the seven geographic regions, Nyakach central had the highest species diversity of 2.15 on Shannon's index.

It was concluded that the genetic diversity of symbiotic and beneficial endophytic bacteria of cowpea in the study area is high, and Nyakach central has the highest species diversity. Contrary to most published work, *Rhizobium* sp. appears to be more competitive in nodulating cowpea. There is a need to establish the symbiotic efficiency of the *Rhizobium* isolates, and whether co-inoculation with plant growth promoting bacteria can enhance growth and yield of cowpea.

**Keywords:** Cowpea, genetic diversity, plant growth promoting bacteria, rhizobia

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## Systemic Infection and Aggressiveness of *Curtobacterium flaccumfaciens* pv. *flaccumfaciens* Analysed by Scanning Electron Microscopy in Different Genotypes of *Phaseolus vulgaris*

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Bacterial wilt due to *Curtobacterium flaccumfaciens* pv. *flaccumfaciens* (*Cff*) ranks first in order of economic importance. It reduces grain yield by colonizing xylem vessels impeding the translocation of water and nutrients to the superior plant parts. Genetic resistance is the most efficient and cheapest way to control this disease in common bean. To obtain resistant cultivars, a genetic improvement programme must consider pathogenic variability, genetic control over pathogen resistance, and methods of evaluating resistant genotypes. This study aimed to analyze, using the scanning electron microscopy, the xylem vessels colonized by the *C. flaccumfaciens* pv. *flaccumfaciens* in resistant, moderately resistant and susceptible genotypes of the common bean plant and identify different levels of aggressiveness of *Cff* isolates, and the horizontal /vertical resistance of common bean genotypes. The isolates were classified into four aggressiveness groups and the most aggressive isolates were BRM 14939, BRM 14942, that cause further reduction in height, differing from the control (non-inoculated plants). Plants inoculated with these isolates showed all symptoms evaluated and higher intensity of disease. It was observed variation in plant height according to the isolates used. In contrast, the less aggressive ones were BRM 14941 and BRM 14946, and the plants showed lower intensity of disease, and symptoms of wilt and flaccidity were more frequent. The genotypes IPA 9, Ouro Branco and Michelite were selected as more resistant among the test isolates. The genotypes Coquinho, BRS Cometa, CNFP 10104, BRS Requite, and A211 exhibited horizontal resistance and the genotypes IPA 9, Ouro Branco, Michelite, BRS Requite, and TU genotypes exhibited specific resistance to the major isolates of the pathogen that causes bacterial wilt. In contrast, the TO, Cornell 49242, IAC Carioca Pyatã, Uirapuru, IPA 7419, PI 207 262, Widusa, IPA 6, Pérola, BAT 477, BRS Esplendor, CNFC 10408, BRS Estilo, Vermelho, BRS Campeiro, IAC Carioca Aruã, AND 277, IAC Carioca Akytã, and IPA 1 genotypes did not contain horizontal resistance to the inoculated isolates. The BRS Cometa, A 211, Coquinho, CNFP 10104, CNFRS 11997, and Frijólica 0-3-1 are highly susceptible to bacterial wilt.

**Keywords:** Bacteria, common bean, disease, genetic control, resistance structures

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## Virulence Diversity of Soybean Rust Isolates from Africa

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Soybean rust caused by the biotrophic pathogen *Phakopsora pachyrhizi* is a highly destructive disease that occurs worldwide causing substantial yield losses. The disease has so far spread across most soybean growing areas in Africa threatening the growing soybean sector. Breeding for resistance is so far the best management strategy for soybean rust. Knowledge about *P. pachyrhizi* virulence is therefore needed to guide development and deployment of soybean germplasm with durable resistance against all pathogen populations. To assess the virulence diversity of *P. pachyrhizi*, 17 isolates from four different African countries were characterised on 11 soybean host differentials with known resistance genes. All the isolates induced tan lesions with abundant sporulation on genotypes without any known resistance genes and on those with resistance genes Rpp4 and Rpp5b. The most durable gene was Rpp2 as 96 % of the isolates induced reddish brown lesions with little or no sporulation. The South African isolate was the most virulent with virulence on six of the host differentials, whereas those from Malawi and some of the isolates from Tanzania had the lowest virulence. Four distinct pathotypes were identified in this study, one each in Kenya, Malawi and South Africa and two in Tanzania representing considerable *P. pachyrhizi* virulence. The three isolates from Malawi and 50 % of the Tanzania isolates were grouped into one common pathotype, suggesting the presence of an identical *P. pachyrhizi* population in those countries. Soybean genotypes carrying Rpp1b, Rpp2, Rpp3, and Rpp5a resistance genes and cultivars Hyuuga and UG 5 were found to be resistant against most of the African isolates and therefore may be useful for soybean-breeding programs in Africa or elsewhere.

**Keywords:** Differentials, *Phakopsora pachyrhizi*, resistance

## African Nightshades and African Spinach Lures Plant Parasitic Nematodes to a Dead-End

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Modern cropping systems are characterised by genetically uniform crop plants. These crop plants are normally cultivated at high densities with very little variation in species composition at both spatial and temporal scales. Consequently, this has fueled the rapid evolution and transmission of crop pests and pathogens such as parasitic nematodes. Parasitic nematodes, particularly root-knot nematodes (RKN: *Meloidogyne* spp.) and potato cyst nematodes (PCN: *Globodera* spp) are plant pathogens of economic importance causing severe yield loss. African nightshades (*Solanum* spp) and African spinach (*Amaranthus* spp) are important leafy vegetables in many parts of Africa as a rich source of nutrition and income. However, their potential use as trap crops for parasitic nematodes remains largely unexplored. Therefore, we tested resistant *Amaranthus dubius* and *Solanum scabrum* as a trap crop for RKN and PCN respectively over 2 years in an experimental station in Kenya. The effects of the 2 trap crop on plant damages and soil infestation were compared with susceptible crop species. After first, second and third implementation of *Amaranthus dubius* trap crop our results show that RKN infestation of the soil decreased by 90, 85 and 90 % respectively, whereas *Solanum scabrum* trap crop decreased *Globodera* spp by 85, 80 and 80 % respectively. Over a period of 2 years, the gall index measured on susceptible *Solanum villosum* decreased from 3.5 to less than 1. To gain some insights into the mechanism behind the suppression of parasitic nematodes by the 2 trap crops hatching and infection assays were carried out. *Solanum scabrum* trap crop stimulated the hatching of *Globodera* spp by more than 65 %. Later, the infection process in both trap crops was blunted by nematode triggered cell death and cell wall reinforcement following nematode detection. Here, we show for the first time the design of a cropping system using resistant African spinach and African nightshades as a trap crop for RKN and PCN, respectively. This approach creates dynamics in cropping systems allowing more diversity to inflict disruptive pressure on RKN and PCN populations and increase the sustainability of agriculture.

**Keywords:** Genetic resistance, sustainable agriculture, trap crop

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## Development of a Certification Program for Virus-Tested Plant Material in Colombia: A Collaborative Initiative

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Crops grown for export in the tropics supplement economies by providing rural income and means of employment, and in certain countries there is a lack of information and continuity to control pathogens. Plant viruses severely affect Colombian crops, and studies indicate that economic losses caused by phytosanitary problems could be avoided with a standard procedure for preventive management. German and Colombian universities, the Colombian Agricultural Institute (ICA), the Colombian Corporation of Agricultural Investigation (CORPOICA), and the International Center for Tropical Agriculture (CIAT) are working together on the initiation of a national agricultural certification program. Three important exports from Colombia have been chosen as model plants for experimentation: ornamental rose (*Rosa* sp.), cape gooseberry (*Physalis peruviana* L.), and purple passion fruit (*Passiflora edulis* Sims). Tests for routine detection of plant viruses affecting these cultivars are being developed based on an inventory of known and novel viruses detected in large and small representative farms in 2016–17. Distribution of known plant viruses affecting rose (PNRSV, TSV), cape gooseberry (PVY), and purple passion fruit (SMV, PFYMV) were investigated by serological (ELISA) and molecular (RT-PCR) techniques. Novel viruses will be identified by application of Next Generation Sequencing (NGS) to pooled samples of diseased crops. Small national producers and larger

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exporters of horticultural and agricultural products can benefit from tools for controlling viral pathogens. The competitiveness of Colombian agriculture in international markets depends on the use of healthy domestic plant material and therefore, virus-free certification can improve quantity and quality of yields and contribute to better trade policy decision-making. The goal of this research is to develop a pilot protocol for routine diagnosis that can be applied in a certification programme for virus-tested plant material for several Colombian horticultural products.

**Keywords:** Certification, Colombia, plant viruses, quality yields, rural livelihoods

## Detection and Characterisation of a New *Ilarvirus* in *Passiflora edulis*

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Colombia is one of the world's main producers and exporters of tropical fruits. Production, commercialisation, and export of these fruits are gaining substantial importance for the Colombian economy. Colombia lacks a robust preventive management programme for the control of plant viruses. In a large project between German and Colombian universities, the Colombian Agricultural Institute (ICA), the Colombian Corporation of Agricultural Investigation (CORPOICA), and the International Center for tropical Agriculture (CIAT), tests for certification of virus-tested plant material are being developed. After banana (*Musa acuminata*) and cape gooseberry (*Physalis peruviana*), purple passion fruit (*Passiflora edulis* Sims) is the third largest fruit export of the country. The consumption of purple passion fruit is expanding worldwide, and due to Colombia's climatic and geographical conditions, the country could play a leading role in this market. Recent studies have shown the presence of a new virus of the *Ilarvirus* genus in Colombian purple passion fruit farms. The spread of this virus could mean drastic reduction of crop yields and major economic losses. Having a good understanding of the biology of this plant pathogen is essential to Colombian farmers for preventing its infection and negative impacts on this crop. For this purpose, molecular biological tools such as nucleic acid isolation, polymerase chain reaction (PCR), and Next Generation Sequencing (NGS) are being used to measure the frequency and distribution of this virus in Colombia, to characterise which symptoms are associated with it, and to identify the pathways for its transmission. This research will contribute to methods for distributing virus-free plant material of *Passiflora edulis* in Colombia, and the protocols developed will be applied to other important Colombian exports.

**Keywords:** Certification programme, *Passiflora edulis* Sims, plant viruses, tropical fruits

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## Impact of Cocoa Cropping Systems and Varieties on Cherelle Wilt, Yield and Foliage Density

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Cocoa tree (*Theobroma cacao* L.) is one of the world's most important perennial crops. In nature cocoa grows in the shaded understorey of rain forests. Due to the increased demand for cocoa in the last decades farmers are removing shade trees and grow cocoa in unsustainable full-sun monocrop systems because this usually results in higher yields. Cocoa yield losses might occur due to several pest and diseases, but also a high number of pods are lost at the very early stage of fruit development, the so called cherelle wilt. It is caused by a physiological reaction of the tree which leads to the abortion of the small pods. This study evaluates the effects of the cropping systems and cocoa varieties on cherelle wilt, yield and foliage density. It was performed in the long-term trial which was initiated by the Research Institute of Organic Agriculture (FiBL) in 2008 in the region Alto Beni in Bolivia. In this trial, 5 different cropping systems are compared, i.e. full-sun monocultures (MONO CONV/ MONO ORG) and agroforestry systems under conventional and organic management (AF CONV/AF ORG) and a successional agroforestry system (SAFS) under organic management. In this study, two commercial varieties (ICS 6, ICS 95), variety TSH 565 of the Trinidad Selection Hybrid and the local cultivars (IIa 22, III 6) were tested. The parameters crown volume, foliage density and light transmission at stem were collected at tree level. With the LAI-2200C plant canopy analyser measurements were made above and below the canopy to determine the light interception. Afterwards the foliage density and crown volume were calculated with the software. A coordinate system to determine the crown volume was created for each tree directly in the field. The lowest cherelle wilt ratio of 34 % was found in the system MONO ORG and the highest 49 % in the SAFS. In all systems, the lowest cherelle wilt ratio was observed in the variety THS 565, whereas variety ICS 95 had the highest. The effect of crown volume, foliage density and light transmission on the incidence of cherelle wilt and production will be shown and discussed.

**Keywords:** Agroforestry systems, crown volume, monocultures, organic farming, systems comparison

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## Impact of Termites on Cocoa Yield under Different Cocoa Cultivation Systems in Cameroon

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Termites are increasingly recognised as a major pests of cocoa cultivation. The trend to cocoa intensification in cocoa agroforests of Cameroon must strongly lead to termite pest outbreaks and affect the cocoa yield. A cross-sectional survey was conducted within five localities of Southern Cameroon along a shade gradient management of cocoa cultivation practised from heavy shaded to unshaded systems. A total of 104 farmers were surveyed to obtain information about termite perception and effect of pest species on cocoa yield in each locality. Overall, 43% of respondents reported termites as a major constraint to cocoa cultivation and placed them in third position after *S. singularis* and borers. In Heavy shaded systems, the most important damages of termites on cocoa trees are observed on stems while in low shaded systems damages are concentrated on roots system related to sudden death of cocoa trees. Globally, the shade trees removal increase cocoa yield in low shaded systems compared to heavy shaded systems. However, the effect of termites on cocoa yield was more important in low shaded systems with up to 50% of yield loss compared only 15% of loss in heavy shaded systems. The agrochemical inputs were significantly higher in low shade systems than in heavy shaded systems and cocoa farms highly infested by termites presented a more high inputs use than poorly infested cocoa farms in the same locality. By foraging on roots system of cocoa trees, termites affect negatively the cocoa health resulting in decrease of cocoa yield and even death of the tree. This study showed that Talba's agroforestry system (intermediate shading system) combining a sustainable cocoa production and some important ecological and economical services especially pest biocontrol, needs to be promoted at large scale.

**Keywords:** Agroforestry systems, cocoa intensification, pest outbreaks, termite

## Improved *Metarhizium brunneum* Endophytism for Biological Protection of Potato Plants

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Conventional insect pest control faces a growing number of problems, such as the decreasing efficacy of many commercial insecticides, the need for repetitive application as well as ecotoxicological issues. Biocontrol with endophytic entomopathogenic fungi is a promising alternative to chemical pesticides to protect crop plants systemically from insect herbivores, paving the way for a novel plant protection measure. Yet, current applications are limited especially by low fungal plant colonisation, a requirement for endophytic biocontrol.

Inspired by penetration mechanisms of plant pathogenic fungi, we aimed at enhancing potato plant penetration and colonisation by the endophytic entomopathogenic *Metarhizium brunneum* strain Cb15 through supplementation of plant cell-wall degrading enzymes pectinase and cellulase or corresponding substrates into beads containing mycelial biomass.

We found that after bead application to potato tubers and incubation at 18–23 °C with a LD cycle of 16:8 for 21 days, *M. brunneum* was re-isolated from surface-sterilized roots, tubers, and shoots in  $75.0 \pm 9.4\%$ ,  $33.3 \pm 9.8\%$ , and  $29.2 \pm 15.1\%$  of samples, respectively. Additional verification of re-isolated *M. brunneum* was conducted with qPCR. Pectinolytic and cellulolytic enzymes were successfully induced by addition of corresponding substrates, but activity levels were low and no correlation between enzymatic activity and fungal penetration was found. However, incorporation of cellulase into beads led to a substantial increase in plant penetration by 25.0% in roots, 54.2% in tubers, and 16.6% in shoots. This was accompanied by a 3.0-fold enhanced spore formation on the surface of beads to  $1.91 \times 10^8 \pm 0.26 \times 10^8$  per bead. Finally, a stronger root development of treated plants was observed indicating a fertilising effect mediated by the formulation.

Our study provides first evidence that refined formulations of endophytic entomopathogenic fungi could contribute to a more effective use of these fungi in strategies priming plants against biotic and abiotic stress.

**Keywords:** Biological crop protection, endophytes, formulation, potato plants

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## Efficacy of the Augmentative Release of *Bracon hebetor* against the Pearl Millet Ear Headminer

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Pearl millet is a staple food cereal crop in the Sahel where it is grown by smallholder farmers for their own consumption. It is a hardy crop with high level of nutrients and can develop on soils with low fertility and in extreme drought conditions. However, the grain yields at farmer fields are far below the potentials. The yield losses are attributable to abiotic and biotic constraints including the millet ear headminer *Heliocheilus albipunctella* the most damaging insect pests, which can destroy up to 85 % in the field. This study aimed at assessing the efficacy of the parasitoid wasp *Bracon hebetor* augmentative release to control *H. albipunctella* in the pearl millet production within the groundnut basin of Senegal. The study area was divided into three homogeneous blocks (northern, southern and eastern parts) where a set of three control villages and three releases villages were taken. The results showed, the millet headminer was the most frequent insect pest in all locations representing 80 % of the samples. Compared to stem borer *Coniesta ignefusalis* and *H. albipunctella* incidence was significantly higher. The natural parasitism by *Bracon hebetor* was around 3 % to 15 % in the the southern and eastern parts of groundnut basin. It was very high in the northern part with 85 % larval mortality. In all villages where the parasitoids were released, an increase in the parasitism level ranging between 9 % and 26 % of larval mortality were noted in comparison with the control villages. In contrast, damages recorded were significantly lower in the villages with parasitoids releases.

**Keywords:** Augmentative release, biological control, *Bracon hebetor*, ear headminer, pearl millet

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## The Project ATTRACAP: Optimisation of an Attract-and-Kill Strategy for Wireworm Control in Potato

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Wireworms, the polyphagous soil-dwelling larvae of click beetles (Coleoptera: Elateridae), are a major insect pest of worldwide relevance causing tremendous yield losses in several crop production systems, like potatoes, maize and other grain crops, oil crops as well as vegetables. Within the last years wireworm damage in potato production substantially increased, both in conventional and organic production systems, resulting in existence-threatening yield losses for farmers. Currently, effective plant protection strategies are not available due to the progressive phase-out of effective synthetic chemicals.

Based on previous projects, an innovative and effective control strategy was developed, using biological components. A capsule releases carbon dioxide (CO<sub>2</sub>) upon contact with the soil humidity, which attracts the wireworms towards these capsules, where they come into contact with an isolate of the entomopathogenic fungus *Metarhizium brunneum*, thus substantially enhancing the frequency of fungal infections of wireworms. The project aims at improving the efficacy levels of in previous projects developed product candidate ATTRACAP®. The innovative formulation technology and resulting beads will be fine-tuned and tested and validated under varying field conditions. Apart from the academic partners, members of the project consortium comprise the company producing the product, and consultants which stay in contact with the farmers and will help with set-up of field experiments. As an outcome of the project an optimised product ATTRACAP® will be available, helping both conventional and organic farmers to maintain a sustainable potato production. This poster will present the first results of the recently started project including field trials 2017. Our formulation will pave the way towards novel “Attract-and-Kill” strategies in pest control.

**Keywords:** Attract-and-kill, biocontrol, biological control agents, CO<sub>2</sub>, entomopathogenic fungi, formulation

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## The Project PICTA-KILL - Novel Strategies for Biological Psyllid Pest Control

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Psyllid pests are distributed all over the world and cause damage in crop plants. Novel defense strategies against these insect pests are of international interest. The use of entomopathogenic fungi as biocontrol agents for reducing psyllid pest populations represents a plant protection method of low risk for nature and humans as well.

Being the vector of *Candidatus Phytoplasma mali*, the infectious agent of apple proliferation, the psyllid *Cacopsylla picta* is responsible for an annual economic loss of a three-digit-million range in Europe. Because there are no direct measures to combat apple proliferation, the vector itself has to be controlled in order to protect the plants. In Germany, there are no authorised plant protection products available, neither for organic farming nor for conventional farming. New insights into the scent preferences of *C. picta* offer innovative options for its control. Hence, the aim of this project is to develop formulations, which can be applied for “Attract-and-Kill”-strategies against *C. picta*. Furthermore, it will be examined if a combination with repellent agents supports the effect (“Push-Pull-Kill”- strategy).

In laboratory and field trials new repellent, attractive and arresting substances, entomopathogenic microorganisms and other insecticides effective against *C. picta* as well as formulation materials and methods for these active ingredients will be screened. For the entomopathogenic microorganisms, cost efficient mass production processes will be developed. Appropriate formulations will be developed and tested in laboratory and field trials. This joint projects cooperates with the Eilenberg group of Copenhagen University on entomopathogenic fungi. First results of the recently started project on strain selection, cultivation, identification of semiochemicals and formulation will be presented.

**Keywords:** Attract-and-Kill, *Cacopsylla picta*, entomopathogenic microorganisms, Push-Pull-Kill

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## **Awareness and Perception about the Occurrence, Causes and Consequences of Aflatoxin Contamination and the Willingness to Pay of Aflatoxin Control in Burundi and Eastern Democratic Republic of Congo**

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Despite efforts to reduce aflatoxin contamination and associated mycotoxin poisoning, the phenomenon continues to pose public health threat in food and feed commodity chains. To support effective development and deployment of technologies and strategies, this study examines awareness and perception of the occurrence, causes, and consequences of aflatoxin contamination among a cross section of 310 farmers in Burundi (160) and eastern Democratic Republic of Congo (DRC) (150). The results show about 53% aware rate within the sampled. Farmer-to-farmer information flow serves as important source of information about aflatoxins. While farmers in Burundi access their information from government extension services, those in eastern DRC obtain information through their own observation. Kendal's concordance rank correlation analysis shown agreement in the perception of the farmers across the two locations. The results showed that the use of contaminated seeds potentially increases the prevalence of aflatoxin contamination. Severity on the other hand is associated with delayed harvesting and the extent of spread of the contamination. Biological factors such as pest and disease attacks also increases the prevalence and severity of aflatoxin contamination. Drought stress and high temperatures followed by high humidity towards harvesting periods increased the prevalence, severity and spread of aflatoxin contamination. The farmers also identified changes in taste, smell, and colour of agricultural produce as signs of contamination. They associated contamination with reported cases of liver infections and low resistance to diseases. This is further compounded by their inability to sell crop at true market values. The results suggest the need to increase awareness among farmers about aflatoxin contamination and associated effects. This require partnerships with actors in the food value chains. There is also the need to examine the extent to which technologies are suitable and affordable for farmers. The willingness to pay was positively influenced by farmers income and knowledge. In order to intervene successfully the aflatoxin control package needed to be a low-cost differentiation in the market that was also credible with farmers. Development of markets that reward growers of aflatoxin free maize with premium prices for their product will further increase adoption of aflatoxin combating technologies

**Keywords:** Aflatoxin, awareness, farmers, Kendal's concordance, perception, willingness to pay

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## Influence of Farming Systems on Aflatoxin Contamination of Groundnut Crops under Field Conditions in Zambia

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Groundnut is one of Zambia's cash and food security crop, and yet it is highly susceptible to pre- and post-harvest aflatoxin contamination. Aflatoxins are carcinogenic, immune suppressant and growth retardant substances that often undermine improved nutritional health status and livelihoods of smallholder farmers in Africa. However, limited information exists on the effect of farming systems on aflatoxin occurrence in Zambian agricultural commodities. This study assessed, on-farm, the impact of agronomic practices on aflatoxin contamination of groundnut. Groundnut samples were collected from different agro-ecological zones of Zambia from the field at harvest and from local markets. Of the 300 analysed samples, the occurrence of aflatoxin was found to be very high with 53 % of harvest and 98 % of market samples testing positive for the contaminant. Total aflatoxin was noted to vary from 0.4–6,095 ppb (harvest samples) and 0.1–5,325 ppb (market samples). Mean aflatoxin contamination level in harvest samples (246 ppb) was higher than the market samples (180 ppb). Contamination of harvest samples, however, was enhanced by the farming practices. The groundnut variety Chalimbana (438 ppb) and Kamulomo (454 ppb) appeared more susceptible than MG5, MG4 or Njute varieties (1.3–203 ppb). Timely planting at the onset of rains (mid-November to mid-December, 67 ppb) reduced aflatoxin contamination by over 5 times when compared to late planting (beyond 20 December, 396 ppb). Growing groundnut in a virgin land or after a fallow period supported less contamination levels (1.4–20 ppb) than when the crop was cultivated in a field where maize (202 ppb) or other legumes (247 ppb) were previously grown. Monocropping (311 ppb) doubled aflatoxin contamination in harvested groundnuts compared to those collected from intercropped fields (132 ppb). The present study confirms the role of good agronomic practices in reducing aflatoxin contamination of groundnut in the field. Farmers need to integrate variety selection with good agronomic practices if they are to consume and market healthy groundnut commodities.

**Keywords:** Aflatoxin, agronomic practices, groundnut, sub-Saharan Africa

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## Networking on Aflatoxin Reduction in the Food Value Chain - AflaNet

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Aflatoxins are naturally occurring, potent fungal toxins in maize and other cereals, spices, herbs and nuts, which are declared responsible for stunting in children and may poison humans and animals even at low concentrations. The frequent occurrence of aflatoxin in food and feed, especially under sub-Saharan climatic conditions, is related to enormous economic losses in the African countries and has a great impact on food safety. Despite the still relevant gain of knowledge and tremendous efforts of the scientific community, the aflatoxin problem has not been solved yet.

The design of the presented project founded by the German Ministry of Food and Agriculture in 2016 is built as an initial study that is planned to be followed by a more intensive, overall collaborative project with European and African partners. The goal of the AflaNet project is to establish a long-term network between scientific and development partners in Kenya/East Africa and Germany to transfer knowledge for reducing aflatoxins in the food value chain. Scientific results have been gathered within the project

- by conducting a carry-over study of aflatoxin into milk,
- about verifying aflatoxin rapid tests and
- to set up molecular methods ensuring the control of fungal contamination.

Information about the extent to which aflatoxins are transferred from the feed into the milk and what content can be found in yogurt and cheese, will be presented. This information is of great importance, because it is not an unusual strategy of farmers feeding their cattle with moulded maize unsuitable for food and consuming the contaminated milk in the diet. In addition it is desirable that less trained persons (such as farmers) should be able to detect aflatoxins simply, quickly and safely in order to ensure the harvested maize (or milk) are of no health concern. Furthermore, improved methods will be reported to determine the conditions which lead to aflatoxin formation, to monitor the growth of *Aspergillus flavus* and to obtain knowledge about the physiology and the behaviour of the fungus.

**Keywords:** Aflatoxin B1, Aflatoxin M1, Africa, *Aspergillus flavus*, carry-over, food safety, fungal contamination, maize, milk, mould, mycotoxin, PCR, rapid test

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## Aflatoxin Distribution in Crop Products from Burundi and Eastern Democratic Republic of Congo

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Aflatoxins (AFs) are noxious secondary metabolites of certain fungal species found in food and feed. Contamination of a commodity is associated with production and storage losses, and subsequently less food availability. Aflatoxins can also pose human health risks and represent a barrier to the development of trade, in both domestic and international markets. In this study, samples of cassava, maize, groundnuts, beans, soybeans, and sorghum, and their processed products were collected from local markets in Burundi and Eastern DRC. In order to investigate the levels of AF, samples were analysed using a single step lateral flow immunochromatographic assay (Reveal Q+). The results revealed the presence of AFs in all samples from both countries, with levels ranging from 1.5 to 2781  $\mu\text{g kg}^{-1}$ . Samples collected from Burundi contained relatively higher levels of AFs. In 51 % of all the crops samples, total AF contamination was above the EU maximum tolerable level of 4  $\mu\text{g kg}^{-1}$ . Processed products, particularly from groundnut, maize and sorghum, had the highest incidence of AF contamination when compared to dried seeds. These results can serve as the basis for strategic and systematic approaches to reduce AF contamination in agricultural commodities in Burundi and Eastern DRC in order to reduce health risk, avoid reduced production in livestock, and open up export markets. To further strengthen the national efforts in abating contamination, risk assessments are proposed in order to establish regulatory thresholds that the local consumer population can depend on, and which can be used to monitor safety across the country.

**Keywords:** Aflatoxins, Central Africa, dairy products, fungi, milk

## **Assessing the Impact of Banana Bunchy Top Disease (BBTD) on Food Security between Men and Women in Affected Communities in West and Central Africa**

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Banana/plantain is a staple crop for smallholder farmers in SSA both for income generation and food security. The perennial crop form the backbone of many farming systems in these regions as it produces fruits all year round while protecting the soil from erosion, providing shade to other crops and surviving floods. Despite its importance, its production is faced with major challenges including Banana Bunchy Top Disease (BBTD). BBTD is spread over 16 countries in SSA and it is estimated to affect about 6 to 12 million smallholders. It threatens banana production and its continuous spread has affected rural livelihoods leading to changes in food and nutritional patterns and gender relations within households. The study seeks to assess the impact of BBTD on food security and nutrition patterns and gender dynamics within households in the affected communities. The study conducted in the BBTD project pilot sites (Cameroon, Benin, Gabon and Nigeria) in Central and West Africa used quantitative and qualitative research approaches with a standardised methodology to collect data from each pilot site. A total of 541 households were interviewed in three communities in each pilot site as addition to focus group discussions and community profiles conducted for men and women separately in each community. Agriculture is the mainstay of smallholder farmers for income generation and food security. Majority of respondents (female and male) cultivate banana for sale and household consumption (79.4 %) followed by respondents who produce solely for sale (18.6 %) and 2 % solely for consumption within the household. Nigeria ranked banana as 1<sup>st</sup> choice crop for men and women, Gabon ranked it 2<sup>nd</sup> to cassava. Cameroon ranked banana as 1<sup>st</sup> choice for women and 2<sup>nd</sup> to cocoa for men. More than 90 % indicated the presence of BBTD which has led to yield and income loss. Introduction of management techniques and the dissemination of clean seeds is vital to curb down the disease and boost production especially given that no varietal resistance to this disease has so far been identified.

**Keywords:** Banana, food security, gender dynamics, smallholder farmers

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## Ecofunctional Management Strategies for *Diaphorina citri* on Organic Orange Orchards

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This study was conducted to develop eco-functional management strategies on organic citrus orchards. The citrus Huanglongbing (HLB) or greening disease is considered as the most destructive and devastating citrus disease worldwide. The bacteria *Candidatus Liberibacter* is the causal agent for the disease and mostly disseminated by the Psyllid *Diaphorina citri*. Therefore, this research explores potential difference in the quantity of natural enemies of *D. citri* in two different weed-management systems for organic citrus production. The weed management included i) an alternate weeding, ii) and a frequent and low weeding, both within the tree rows. The on-farm study was conducted in Mexico, Veracruz on a 2 years old organic orange (var. Valencia) orchard under a systematic line sample design. Data was taken from 5<sup>th</sup> of February till the 18<sup>th</sup> of March. Measurements were conducted in total 3 times for the weed composition and 5 times concerning Arthropode diversity. Along transects randomly ten square metre of floral composition were determined on species level. Afterwards the alpha and beta biodiversity are calculated with the Shannon-Wiener index, the evenness and the beta biodiversity with the Jaccard's index. *D. citri*, Coccinellidae and Crysopidae were observed on 4 sprouts of each 3 selected tree/treatment with a magnifying glass. With an insect net, the arthropod populations on the ground between the trees were caught and placed into polyethylene bags with alcohol 70%. Afterwards, the insects were counted and divided into the different orden level. Preliminary results show that there was no difference in the weed composition concerning family level. The species number was on the second and third observation date higher in the treatment with alternate weed management, 57 and 51 species against 53 and 45 in the low weed management but the Shannon index was higher for the low mowing weed management. *D. citri* population was not significantly different among treatments (correlation of 0.34). However, the amount of *D. citri* was lower in the alternate weeding compared with the frequent weeding. That is in contrast to the other arthropods, which were abundant in higher numbers in the alternate weed management. The amount of natural enemies decreased strongly after the second observation and was the same for both treatments.

**Keywords:** Beneficial insects, eco-functioning, Huanglongbing, management

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## Efficacy of Commercial and Non-Commercial Fungal Isolates for Suppression of Root-Knot Nematode on Pineapple

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Kenya ranks among the top five pineapple exporters in the world. Canned pineapple is the largest single manufactured export in Kenya making pineapple an important commodity in monetary terms. Pineapples are hosts to one or more species of plant-parasitic nematodes and are responsible for considerable yield losses. The presence of *Meloidogyne javanica* in root or soil samples has been associated with crop losses. To secure yield and profits, the extensive use of soil fumigants is currently unavoidable for the management of these plant-parasitic nematodes. However, the adverse impact of these pesticides on human health and the environment is evidently a major concern and alternatives that are economically competitive are urgently needed. Biological control is being considered as part of an integrated strategy for the management of plant parasitic nematodes in Kenya. Several native commercial and non-commercial biological control products that possibly meet these criteria have been identified. The work presented evaluates the efficacy of endophytic and saprophytic native fungal isolate against *Meloidogyne javanica* on pineapple. *Trichoderma asperellum* M2RT4 (ICIPE), *Purpureocillium lilacinum* (dudutech), *Trichoderma asperellum* (dudutech), *Purpureocillium lilacinum* (KBL) were tested. Two approaches were adopted to evaluate the efficacies of the selected fungal isolates, (1) an *in vitro* assay to investigate the effect of culture filtrate of selected fungal isolates on egg hatching and juvenile mortality, and (2) the effect of the selected fungal isolates on nematode development was studied in pot trials. Rooted pineapple plants were drenched with a conidial suspension of  $1 \times 10^8$  conidia ml<sup>-1</sup> of each fungal isolate and then infected with *Meloidogyne javanica*. After 12 weeks, plants were uprooted and evaluated for efficacy of the products. Of the four fungal isolates tested *in vitro*, *Trichoderma asperellum* isolate M2RT4 provided the best biocontrol efficacy *in vitro*, It reduced root-knot nematode egg hatching 100 % as compared to other fungal isolates, the same isolate causes 100 % second stage juvenile paralysis 5 hours after fungal filtrate application with 97 % recovery when transferred into distilled water. Pot assay fails to demonstrate the ability of fungal isolates to successfully reduce nematode penetration, galling and reproduction of *Meloidogyne javanica*. This study provide the potential of *Trichoderma asperellum* M2RT4 for use against *Meloidogyne javanica* as an egg pathogen. These results indicate that most fungal biocontrol agents can cause total nematode paralysis not necessarily mortality with nearly 100 % nematode recovery after 7 – 9 days.

**Keywords:** Biological control, pineapple, root knot nematodes

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## Plant Derived Oils as Ultraviolet Protectants for the Beet Armyworm Nucleopolyhedrovirus (SeNPV)

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Ultraviolet B (UVB) from sunlight is the main constraint to using the environmentally friendly baculovirus in plant protection, especially in tropical and subtropical countries. Eleven oils emulsified with lecithin were evaluated as UV protectants to improve the persistence of the beet armyworm nucleopolyhedrovirus (SeNPV) in the laboratory. Seven of these (cotton seed, olive, flax, soybean, black seed, wheat germ and safflower) at a concentration of 1 % provided UV protection compared to virus alone (with lecithin) treatment irradiation under UVB for 30 minutes in the laboratory. There was a relatively high rate of protection when plant derived materials, i.e., henna, clove, skullcap, peppermint and Marasperse® (lignin), at the concentration of 0.25 %, were mixed with cotton seed oil at 1 % and exposed to UVB light for 5 hours. The absorption spectra of the materials, either tested singly or in combination with plant derived materials, was reflected in the absorption spectrum, with more absorption providing more protection against UVB.

Field trials with collard showed that the virus alone (with only H<sub>2</sub>O) rapidly lost its activity after 2 days. The original activity remaining (OAR%) values were 86.66, 41.37, 0.0 and 0.0 % after 1, 2, 4 and 7 days, respectively. Whereas, addition of cotton seed oil emulsifier to black tea provided the highest rate of protection with OAR% of 96.55, 63.33, 34.62 and 17.24 % for the same days after treatments, respectively. Also, addition of cotton seed oil emulsifier to the lignin provided UV protection to 100, 58, 43.33 and 3.33 % respectively for the same exposure times under sunny days. The study recommends using of natural oils to improve the persistence of baculoviruses.

**Keywords:** Additives, baculovirus, oils, protectant, ultraviolet

## Host-Preference and Parasitic Capacity of Five *Trichogramma* Species (Hym.: Trichogrammatidae) against some Stored Product Moth Pests

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The host-preference and parasitic capacity of four local *Trichogramma* spp. towards four species of stored product moth eggs were investigated in laboratory experiments in order to select new candidate species for inundative releases against lepidopterous pests in storages. Experiments were carried out by offering a single parasitoid female to eggs of the Indianmeal moth *Plodia interpunctella* (Hubner), the Mediterranean flour moth *Ephestia kuehniella* Zeller, the warehouse moth *E. elutella* (Hubner), and the almond moth, *Cadra cautella* (Walker) in choice and no-choice assays. The *Trichogramma* species were collected from arid and semi-arid areas in Egypt. These were *T. bourarachae*, *T. cordubensis*, *T. euproctidis*, *T. cacociae*, and their efficacy was compared with the common wasp used commercially for biological control of stored product pests (*T. evanescens*). The bioassay for host-preference of *Trichogramma* was carried out by offering a single wasp female the choice between equal numbers of host eggs on square cards "Petri dish tests" and /or strip cards "strip card tests". In Petri dish tests, *E. kuehniella* was a highly acceptable host species for *T. bourarachae*, *euproctidis*, and *cacociae* wasps. While *elutella* and *cautella* eggs were more acceptable for *evanescens* and *cordubensis*, respectively. In strip card tests, *E. kuehniella* eggs were highly acceptable for *bourarachae*, *cacociae* and *evanescens*. Eggs of *elutella* and *cautella* were more acceptable for *euproctidis* and *cordubensis*, respectively. Also, the comparative study of parasitic capacity of the *Trichogramma* spp. was carried out under 'no choice conditions' by exposing a freshly emerged single wasp to an unlimited number of host eggs. Significant differences were found among the parasitic capacity of the tested *Trichogramma* spp.: *T. borarachae* showed a good parasitic potential against *S. cerealella* and *E. kuehniella*; *T. evanescens* and *T. cacociae* against *S. cerealella*; *T. cordubensis* against *S. cerealella* and *P. interpunctella* and *T. euproctidis* against *P. interpunctella*. However, dissection of host eggs with wasp-emergence holes showed that all tested wasps had a propensity to superparasitize the host eggs. *T. cordubensis*, *T. euproctidis* and *T. borarachae* showed promise for further investigation into selecting new biological control agents against stored product lepidopterous pests.

**Keywords:** Parasitisation capacity, superparasitism, host preference

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## Performance of *Metarhizium anisopliae* (Metsch.) Sorok and *Beauveria bassiana* (Bals.) Vuill. Isolates against Cowpea Aphid (*Aphis craccivora* Koch) in Cowpea

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Cowpea *Vigna unguiculata* L. Walp is an important indigenous leafy vegetable grown in the tropics mainly as an inter crop with cereals. It is drought tolerant and improves soil fertility. Cowpea production in the tropics is below world production records mainly due to damage by arthropod pests and among them cowpea aphid, *Aphis craccivora* Koch, is a major pest causing direct damage by removing plant sap and indirectly by transmitting viral diseases. Chemical pesticides used in management of cowpea aphid have undesirable effects including toxic residues on food, indiscriminate killing of beneficial arthropods, are expensive and lead to development of resistance. Entomopathogenic (EPF) based biopesticides offer a sustainable alternative to chemical pesticides in the management of cowpea aphid as they are environment and user friendly and are compatible with other IPM strategies like biological control. Two isolates of *Metarhizium anisopliae* (ICIPE 62 and ICIPE 41) and one *Beauveria bassiana* (ICIPE 644) isolate which caused 90, 80 and 75 % mortality respectively to cowpea aphid under laboratory conditions were evaluated under field conditions for two seasons for their performance against cowpea aphid. Conidia in oil formulation was applied at the rate of  $1 \times 10^{12}$  conidia ha<sup>-1</sup>. In the first season, characterised by high rainfall and late and low aphid infestation, the isolates did not result in significant reduction in aphid population density and leaf yield gain compared to control. However, in the second season with reduced rainfall and early and high aphid infestation all the isolates recorded significantly reduced aphid densities compared to control. Furthermore, ICIPE 62 recorded lowest aphid density compared to ICIPE 41 and ICIPE 644. There was however no significant difference in leaf yield between the biopesticides and control even though biopesticides treated plots produced better quality leaves for consumption. This study confirms the efficacy of the three isolates against *A. craccivora* and the potential of ICIPE 62 as promising biopesticide. The results also show that efficacy of fungal based biopesticides is dependent on prevailing environmental conditions and therefore the need to improve their performance under different environmental conditions.

**Keywords:** Biopesticide, entomopathogenic fungi, mortality

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# Biomass, biofuel and bioeconomy

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## Oral Presentations

- LISA BIBER-FREUDENBERGER, JAN BÖRNER:  
**The Global Bioeconomy Landscape: What Determines National Strategic Choices?** 99
- GLEICE ALVES DE SOUSA, JOACHIM WERNER ZANG, WILSON MOZENA LEANDRO, ATHAYDES F. LEITE, SUELENE VAZ DA SILVA, WARDE ANTONIETA DA FONSECA-ZANG:  
**Study of Implementation of Biogas Production in the Fruits and Vegetables Wholesale CEASA-GO, Goiás, Brazil** 100
- FLORIS DALEMANS, MIET MAERTENS, BART MUYS:  
**Adoption of Agroforestry-Based Biofuel Programs: A Case Study in Hassan District, India** 101
- TILAHUN WOLDIE MENGISTU, SAURABH GUPTA, REGINA BIRNER:  
**What Do Smallholder Maize Growers Do with their Maize Biomass? Empirical Evidence from the Maize Belts of Ethiopia** 102
- NAZIA YASMIN, PHILIPP GRUNDMANN:  
**Intra-Household Barriers in the Adoption of Alternate Technology: A Case of Biogas Technology in Pakistan** 103

## Posters

- HABTAMU DEMILEW YISMAW, BAMLAKU ALAMIREW ALEMU, TIM K. LOOS:  
**Is Bamboo a Poor Man's Timber in Ethiopia? Employment Prospects of Bamboo among Poor Rural Farm Families** 104
- CHRISTINE SCHMITT, NIKOLAS BOEHLKE, RAYMOND JATTA, JELANA VAJEN, MANFRED DENICH:  
**BiomassNet: The First Expert Network for Food and Non-Food Biomass in Africa** 105
- CHEN QIU:  
**Biomass Energy Use, Price Changes and Labour Allocation in Rural Areas: An Agricultural Household Model-Based Analysis** 106

SEBASTIAN AWISZUS, SAJID LATIF, JOACHIM MÜLLER: <b>Evaluation of the Bio-Methane Potential of By-Products from Cassava Starch Processing</b>	107
ROBERT GUMISIRIZA, OLIVER HENSEL, JOSEPH HAWUMBA: <b>Processing of East African Highland Green Bananas: Banana Waste Characterisation for Bio-Energy Production in Uganda</b>	108
MATHIAS NEUMANN ANDERSEN, SELORM Y. DORVLO, EMMANUEL AMOAKWAH, JOSEPH O. EDUAH, KWADWO KUSI AMOAH, ERIC O. DANSO, ISAAC BAIDOO, FINN PLAUBORG, EDWARD B. SABI, STEPHEN ABENNEY-MICKSON, ULRIK HENRIKSEN, JESPER AHRENFELDT, KWAME A. FRIMONG, MARK ABEKOE, HENRIK BREUNING-MADSEN, KINGSLEY J. TAAH, FULAI LIU, DANIEL SARPONG, SIMON BOLWIG, FAUZIATU AHMED, EMMANUEL ARTHUR: <b>Green Cohesive Agricultural Resource Management – The WEBSOC Project</b>	109
MICHAEL NASSL, TINA BEUCHELT: <b>Is Food Security Sufficiently Taken into Account in Estimates of Global Biomass Potentials for Non-Food Uses?</b>	111
JAN JANOSCH FÖRSTER, NEUS ESCOBAR: <b>Life Cycle Thinking in Governance: The Case Study of Bioplastic Production in Thailand</b>	112
JAN BÖRNER, LISA BIBER-FREUDENBERGER, NEUS ESCOBAR, JAN JANOSCH FÖRSTER, ANGELA GUBELT, KIRSTEN SELBMANN-LOBBEDEY: <b>An Interdisciplinary Framework for Sustainability Assessment in the Global Bioeconomy</b>	113
EEFKE MOLLEE, MORAG McDONALD, KATJA KEHLENBECK: <b>Plant Species Richness and Diversity in Urban Uganda: An Inventory of Kampala’s Homegardens</b>	114
KATJA KEHLENBECK, JUSTIN ORINA, JOHN BOSCO MUKUNDI, FREDAH KARAMBU RIMBERIA, MONICA A. OMONDI, JENS GEBAUER: <b>Population Structure and Tree Densities of Baobab (<i>Adansonia digitata</i> L.) in Kilifi County, Kenya</b>	115
LIANA KINDERMANN, ANKE S.K. FRANK, KINGSLEY AYISI, STEFAN FOORD, VINCENT MOKOKA, LOURENS SWANEPOEL, PETER JOHN TAYLOR, ANJA LINSTÄDTER: <b>Assessing Functional Biodiversity in (Sub-)Tropical Agricultural Landscapes: Lessons from South Africa’s Vhembe Biosphere Reserve</b>	116

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## The Global Bioeconomy Landscape: What Determines National Strategic Choices?

LISA BIBER-FREUDENBERGER, JAN BÖRNER

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An increasing number of countries worldwide develop bioeconomy strategies to promote a stronger reliance on the efficient use of renewable biological resources in order to meet multiple resource scarcity and sustainability challenges. Especially for developing countries, with a high potential of biomass production, bioeconomic strategies have been promoted to be a pathway of future sustainable development. This however has also been criticised for neglecting negative effects in terms of land and food competition, social impacts, biodiversity loss and environmental degradation. However, bioeconomies are diverse with sectors, such as agriculture, forestry, energy, paper and pulp, textiles, chemicals and pharmaceuticals as well as science and education in very different stages of development. We thus also expect large variation in the factors driving sustainability outcomes of bio-based development strategies and the appropriate strategies to promote them. Ideally bioeconomy strategies thus reflect the comparative advantages of countries in pursuing one or the other bioeconomic development pathway. We present a typology of bio-economies based on country-specific characteristics, such as 1) the relative importance of bio-based economic sectors as well as their capital and skill-intensity, 2) competitive advantages including natural resource endowments and education 3) openness to and role in international trade. We first compare the resulting bioeconomy clusters against the strategic focus and implementation status of their dominant bioeconomic development strategy. In a second step, we assess the clusters in terms of their sustainability performance using SDG related indicators. We hypothesise that distinct bioeconomy types can be identified with characteristic performance levels of key sustainability indicators and varying scope for tradeoffs and synergies. Our final discussion centres on the implications of the results for the debate on international regulatory frameworks to govern bioeconomic change.

**Keywords:** Bioeconomy, strategies, sustainability, typology

## Study of Implementation of Biogas Production in the Fruits and Vegetables Wholesale CEASA-GO, Goiás, Brazil

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The Brazilian state owned central distribution centres for fruits and vegetables were created in the sixties and implemented in the state of Goiás in 1975 to attend regional, mostly family owned producers and clients. The goals of this work were to study composition, quantities and disposal of solid residues generated at CEASA-GO along one year, observing seasonal changes, among costs involved in transport and deposit of these, as well as electric energy consumption on place. It was evaluated the monthly potential of the generation of electric and thermal energy from biogas produced from these residues, as well as the use of the generated digestate from biogas fermentation as fertiliser. Systematic bibliographic research, data collection by interviews raising numbers of individual residues sorted by type, like e.g. pineapple or tomato, along a one year period was combined with the biogas potential of these substrates. The biogas potential for special substrates, like the Cerrado fruit “Pequi” (*Caryocar brasiliense*), where no literature data were available have been determined in the biogas lab by batch experiments with an automated AMPTS-II system, BioProcessControl, Sweden. Transformation of the biogas to energy was simulated and compared to the own consumption. Based on complete data of 2015 the results show the possibility to supply all electric energy consumed by CEASA of over 500 kW by biogas generation from a part of more than 90,000 tons of organic residues remaining annually. A relatively fast return of investment by the reduction of costs for electric energy (approximately 80,000 € per month), reduction of waste transport and deposit costs, and potential gains by selling the generated fertiliser, is expected. Environmental gains could be predicted by avoiding greenhouse gas emissions from deposits on landfills, reduction of transport impacts, raising use of renewable energy and production of organic fertilisers. This could provide an example for the state wholesales of all 26 Brazilian states.

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**Keywords:** Biofertiliser, renewable energy, waste management

## **Adoption of Agroforestry-Based Biofuel Programs: A Case Study in Hassan District, India**

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Local production of liquid biofuels has been widely considered in the South as a strategy towards energy security in remote areas depending on fickle fossil fuel markets and isolated from centralised electrification grids. In particular, much hope is set on biofuels derived from non-edible feedstock grown on marginal or underutilised lands, thereby trying to prevent interference with food production and food markets. This has given rise to many biofuel projects based on wasteland plantations, but their implementation faces many technical, ecological, socio-economic and institutional challenges, and many projects have failed to gain momentum. In this empirical case study, we investigate an alternative biofuel model in Hassan district, South India, which promotes the cultivation of various native oilseed trees in agroforestry systems on smallholder farms through training and planting programs, marketing support, cooperative establishments and distribution of processing equipment. Using an extensive survey with 396 local smallholder farmers, we aim to understand how context-specific factors play a role in smallholders' decisions to adopt the proposed biofuel model or not. Our analysis confirms that multiple barriers exist towards smallholder adoption, including labour and land opportunity costs, poor economic viability, ecological cultivation constraints, lack of knowledge on the value chain, and aversion towards revenue lags. The main implication is that even for these low input – high diversity – high resilience (LIHD) agroforestry-based systems with their associated multiple uses and co-benefits, not only opportunities but also constraints exist towards smallholder adoption. *Ex-ante* assessments of these context-specific determinants of (dis)adoption and rigorous performance evaluations are crucial to programme design, targeting and value chain establishment.

**Keywords:** Agroforestry, biofuels, energy security, smallholder adoption

## What Do Smallholder Maize Growers Do with their Maize Biomass? Empirical Evidence from the Maize Belts of Ethiopia

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Cereals are main contributors of growth of Ethiopia's agriculture based economy. Despite high cereals biomass potential and yield gaps, achieving food security, however, remains a challenge. Earlier studies attributed to decisions on production and productivity augmenting factors as the main reasons for food insecurity and poverty paying no attention to decisions on the utilisation of biomass. This study therefore tries to examine maize farmers' decisions on the uses of maize biomass, extent of use and its implication on food security and the challenges therein. The study follows a mixed methods approach that involves both qualitative and quantitative techniques. Data were collected through key informant interviews, focus group discussions and household survey with 322 randomly selected farmers in two districts. Intensity of biomass use and households' food security, respectively, were measured using proxy indicators, Herfindahl-Hirschman Index and Food Consumption Score. We examined the implication of intensity of biomass use decision on food security using an endogenous switching regression model. The study finds that more than half of the total biomass has been used for non-direct food purposes. The findings ascertain the importance of post-production decisions on the uses of maize biomass to ensuring of household food security. Our endogenous switching regression model further provides a compelling evidence of impact of diverse use decision on food security. The study further identifies factors such as markets, extension and information access as key determinants influencing post-production decisions on the uses of maize biomass. The findings therefore underscore the importance of integration of post-production decision on the uses of maize biomass into the maize sector's development strategy. Institutional innovations, particularly in the research and extension systems, and integration of maize growers into markets are decisive to fully unlock the food security potential of maize.

**Keywords:** Biomass uses, challenges, ESR, food security, institutional innovations, markets, research-extension systems, use diversification

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## **Intra-Household Barriers in the Adoption of Alternate Technology: A Case of Biogas Technology in Pakistan**

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In designing agricultural policies households are considered a single decision making unit but theoretical and empirical literature on intra-household decision making has suggested that individuals can have divergent preferences, objectives and welfare implications within a household. So, the assumption of unitary model in household decision making can be misleading particularly for those technologies which have diverse division of labour and welfare impacts on male and female in the household. In this scenario, it is necessary to understand the internal dynamics of household to understand the barriers to the technology adoption. This study in rural Pakistan sets out to examine the behaviour of male and female household members towards the biogas technology adoption. To meet this objective theoretical framework was mainly adapted from the theory of planned behaviour including bargaining process and other sources of perception and socio-cultural influences as stimuli of adoption. Data were collected through focus group discussions and structured questionnaire with males and females in the households. Structural equation modelling (SEM) technique was applied to test the strength of the hypothesised relationships. Our findings highlighted the importance of gender among other barriers in slow transition towards biogas technology. It also showed that the decision to adopt biogas technology is not only affected by the physical availability and needs of the actors but is also differentiated by their power relations vested in variety of social norms, cultural settings and societal construction and have different impact upon different actors. These findings hint at the appropriate actions from policymakers and donors to develop such intervention strategies sensitive to gender specific needs.

**Keywords:** Adoption barriers, biogas, gender, intra-household decision

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## **Is Bamboo a Poor Man's Timber in Ethiopia? Employment Prospects of Bamboo among Poor Rural Farm Families**

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The primary objective of the research is to provide holistic insights into the current status and future potentials of the bamboo sector to enhance sustainable livelihoods and employment generation amongst poor rural farm families in Ethiopia. The research mainly used primary data for analysis. The sample for the research is drawn from the two-major bamboo growing hot-spots in Ethiopia. A total of 486 sample households were randomly selected from these areas. The research applied integrated qualitative as well as quantitative analysis techniques. The corner solution model developed by Cragg (1971), as an alternative to the Tobit model, is used to analyse the employment contribution of bamboo to the rural smallholder farm households. Findings of the research show that bamboo has a notable contribution to employment among poor rural smallholder farm households. Engaging in bamboo is more preferred by poorer rural families with relatively lower resource settings. Results also show that entering into bamboo employment is not a problem, yet, employment in bamboo is only subsistence. Moreover, market prices of bamboo culms are found to have a significant contribution for both the probability of employment in bamboo as well as for the conditional probability of the variation in the income from bamboo of rural households. All in all, employment in bamboo is income elastic and dominated by poorer farm households which have relatively higher share of income from bamboo than others. Besides, higher level of income from bamboo has a strong association with better food security status of rural farm households. Moreover, the fact that it can be harvested in short cycles makes bamboo the most liquid cash crop for farmers especially in times of short run food shortage. These evidences collectively imply that employment in bamboo is a safety-net to meet food security specially among poorer rural families. Accordingly, the research forwarded areas of intervention to enhance the contribution of bamboo to employment generation and maintain sustainable livelihood among poor rural farm households. These include, among others, collective training and capacity building schemes for farmers and artisans, distribution of improved bamboo varieties among farmers and creating enabling market infrastructure.

**Keywords:** Bamboo biomass, employment, sustainable agricultural livelihoods

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## **BiomassNet: The First Expert Network for Food and Non-Food Biomass in Africa**

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Global demand for biomass as food, feed, a source of energy and industrial raw materials is putting increasing pressure on the agricultural sector and food production worldwide. This is a particular challenge for Africa where many countries still struggle to achieve food security, while facing new demands for biomass as a source of income, energy and industrial raw materials. The creation of future development pathways for the African agricultural sectors is thus a complex task and requires exchange and cooperation between experts from different disciplines and sectors. To facilitate this exchange, the first expert network for food and non-food biomass in Africa (BiomassNet) was initiated in 2016 by the Center for Development Research (ZEF) and the Forum for Agricultural Research in Africa (FARA) within the framework of the BMBF-funded research project BiomassWeb - Improving food security in Africa through increased system productivity of biomass-based value webs. BiomassNet aims at supporting African countries in achieving food security and developing sustainable bioeconomies through the exchange of knowledge and expertise between experts from science, policy and practice. The network is open to all disciplines and all sectors who address food and non-food biomass issues in Africa, including for example scientists and experts from governmental and non-governmental organisations, development agencies, or the private sector. BiomassNet is implemented through an interactive website that allows users to create profiles, to contact each other and to upload and download information. In addition, the BiomassNet Dgroup that currently has 417 members from 46 countries provides a platform for moderated email discussions. The first Dgroup discussion on 'Post-harvest cassava technology and value addition' was rated as highly useful by the participating experts. The BiomassNet website will be launched in July 2017 and will form part of the ongoing FARA capacity building and outreach activities. In conclusion, we will highlight the lessons learnt from setting up the BiomassNet expert network and discuss its possible contribution to shaping future development pathways and strategies for agricultural systems in Africa.

**Keywords:** Bioeconomy, capacity-building, exchange, food security, future agriculture

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## **Biomass Energy Use, Price Changes and Labour Allocation in Rural Areas: An Agricultural Household Model-Based Analysis**

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As a kind of renewable resource derived from biological materials, biomass energy provides a link between agriculture and human living. It plays an important role in agriculture-based rural livelihoods. Building on the growing interest in the role of biomass energy use in poverty reduction and food security, the main objective of this study is to robustly investigate how different positive and negative price shocks in exogenous markets potentially influence household biomass energy using behaviours under the imperfect labour market in rural China. Since household's consumption, production and labour allocation decisions are interlinked, the impacts of exogenous price changes on biomass energy use are complex. Thus, a comprehensive analysis framework is thus developed in this paper based on an agricultural household model. The total behavioural effects are estimated by adopting a two-stage estimation strategy: the shadow wage of household labour is firstly estimated and then used to estimate consumption and labour demand systems. The results show that the effects of price changes on household biomass energy use include a direct (i.e. the supply or demand responds to an exogenous shock) and an indirect (i.e. the supply and demand adjustments to the endogenous variations in the shadow wage induced by this exogenous shock) component. In addition, neglecting the indirect effect can bias the final effect on household biomass energy using behaviours, implying that market failures reduce the flexibility in household's behaviours. The findings of this paper also provide important policy implications for future biomass energy development: the market prices should be adjusted to control the demand for biomass energy, and the measures aiming at eliminating the market failures should be attached importance at the same time.

**Keywords:** Agricultural household model, biomass energy use, exogenous price changes, labour allocation, rural livelihoods

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## Evaluation of the Bio-Methane Potential of By-Products from Cassava Starch Processing

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Aim of the present study is to examine the bio-methane potential of cassava root peels and cassava pulp. The study especially focusses on trace elements essential for bacteria involved in bio-methane production process. Cassava peels from Tanzania and cassava pulp obtained from fresh cassava purchased from a local distributor in Stuttgart, Germany, were analysed regarding the content of Co, Mo, Ni, Se, Fe and Mn. Extended Weender analysis was conducted to investigate on the amount of degradable and less degradable fractions in the chosen substrates. C/N ratio as an indicator for substrate quality in terms of conditions required by methanogenic bacteria was determined. Expectable bio-methane yield was determined based on Hohenheim Biogas Yield Test (HBT) following standard VDI 4630.

Results showed a lignin content of 10 % dry matter basis for peels and 0.3 % dry matter basis for cassava pulp. Detected C/N ratios were within a suitable range for bio-methane bacteria but contents of essential trace elements in general are lower than the concentration recommended in literature for practical applications. HBT shows a total biogas potential of  $0.443 \text{ m}^3 \text{ N kg}^{-1} \text{ DM}$  for cassava root peels and  $0.450 \text{ m}^3 \text{ N kg}^{-1} \text{ DM}$  for cassava pulp resulting in a bio-methane yield of  $0.225 \text{ m}^3 \text{ N kg}^{-1} \text{ DM}$  for peels and  $0.224 \text{ m}^3 \text{ N kg}^{-1} \text{ DM}$  for pulp, respectively.

The study shows the necessity for adding essential trace elements for establishing a stable bio-methane process if cassava by-products are utilised. This can be realised by using mixtures of cassava products and animal manure. Results further indicate that investigated by-products of cassava starch processing have an utilisable bio-methane potential, which can contribute to an environmentally friendly energy supply of the cassava starch processing industry and prevent pollution caused by uncontrolled dumping.

**Keywords:** Bio-methane potential, cassava by-products, cassava starch processing, trace elements

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## Processing of East African Highland Green Bananas: Banana Waste Characterisation for Bio-Energy Production in Uganda

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World over, agro-processing is a high energy consuming enterprise that in-turn generates a lot of waste residues. Uganda is the second largest global producer of bananas and the industry generates different waste fractions both at production and banana fruit processing. However, no thorough auditing and characterisation of such waste had been done to guide potential value addition through bioenergy production. This study therefore aimed at assessing general banana processing, waste management methods, characterisation of waste residues and evaluation of wastes' potential for biogas energy production through anaerobic digestion. The results revealed that methods for management of these wastes were mainly by dumping, reuse as mulching materials and animal feeds, as well as use of dried fraction for fuel. The study further indicated that processing of a unit bunch of green bananas generates 40 % as pulp and 60 % as total waste residues with total waste to pulp ratio of 1.5 and peel / pulp ratio of 1.3. Laboratory waste analysis indicated that the waste contained high moisture content; 90 % and 83 % for peduncle and peels respectively. The high moisture content suggests that banana waste is amenable to biochemical conversion technologies and would require minimal additional water requirement thus reducing water costs. Other analysis results indicate that waste was highly organic with more than 80 % of the total solids as volatile. However, the waste had higher carbon content than total nitrogen that translated into higher C:N ratio of 41 in mixed waste. Furthermore, the lignocelluloses content of the waste comprised of 21.16 %, 10.46 % and 11.31 % for cellulose, hemicelluloses and lignin, respectively. The current waste management methods were found to be neither efficient nor profitable, thus research into economically viable options for waste utilisation and reduction strategies is imperative. In conclusion, the physic-chemical characteristics of banana waste make it favourable for bioenergy production through anaerobic digestion. Appropriate waste pre-treatment would enhance the process for improved energy yields.

**Keywords:** Banana processing, banana waste, bio-energy, bio-gas production, waste characterisation, waste value addition

## Green Cohesive Agricultural Resource Management – The WEBSOC Project

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The present growth in Ghanaian food and energy production to support an increasing population is not sustainable as it depends on deforestation with little increase in productivity per unit of land (EC, 2007). The overall objective of the WEBSOC project is to promote growth and employment through research on green, cohesive Water, Energy-from-Biomass, Soil, Organics, and Crop to devise ways to reverse this trend and enhance livelihood in rural communities by increasing agricultural productivity and employment.

The project has developed reactors for using crop residues to produce biochar and wood gas for artisanal palm oil refineries (Dorvlo, *ibid.*) to lessen the pressure on forests for firewood and charcoal and as an intelligent way of recycling organics and reducing CO<sub>2</sub> emission. The application of the biochar to agricultural fields has increased soil carbon sequestration (Amoakwah, *ibid.*) and thereby represents a CO<sub>2</sub>-negative approach to sustainable increase soil fertility (Eduah, *ibid.*), crop yields (Amoah, *ibid.*), and carbon storage. Further intensification has been achieved by developing small-scale solar drip fertigation systems allowing one to two more growing

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seasons per year to produce high-value crops (Danso, *ibid.*). Thus the project has devised a triple-win situation where farmers get sustained higher yields (from irrigation and improved soil fertility), CC gas emissions are reduced (from increased carbon sequestration), and small scale industries and households get energy (from pyrolysis of crop residues). Finally, agricultural value chains (Baidoo, *ibid.*), both on the supply and processing side, are under development in cooperation between local SMEs and universities. The research into these options has been pursued within a framework designed to educate PhD students and young scientists.

**Keywords:** Biochar, Ghana, irrigation, small-scale farming, sustainable intensification

## Is Food Security Sufficiently Taken into Account in Estimates of Global Biomass Potentials for Non-Food Uses?

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Given the finiteness of the global petroleum reserves accessible to humans, the need to find ways to replace energy from fossil fuels with fuels from alternative sources is apparent. Global awareness to this predicament has been growing over the recent decades. As a result, biofuels, bio-oils, biogas and other biomass uses for industrial purposes have become important non-fossil replacements. Consequently, the demand for biomass for non-food use is steadily growing but arable land and hence biomass resources are limited despite being 'renewable'. Over the last 20 years a growing body of scientific research engaged in modelling the future biomass potentials, especially for energy uses. This research aims to review how and to what degree food security dimensions are reflected in estimates of biomass potentials for non-food uses. A systematic literature review showed that the predicted future biomass potentials are highly divergent. This is mainly due to the heterogeneity of methodologies, assumptions and datasets employed. Fundamental to all approaches, however, is the question of how to balance land availability for energy production with land resources required to secure food provision. Yet, despite being a central element of the modelling approaches, food security is so far not well included in these models. Most studies ignore a balanced dietary composition (e.g., vitamin or micronutrient requirements) and food requirements are typically reduced to basic per capita caloric intake. The per capita intake is then extrapolated to 'world regions', underrepresenting in most cases local disparities in food availability or socio-economic access. Moreover, several of the basic assumptions regarding future agricultural intensification, yield growth or consumption patterns (e.g., a drastic reduction in animal protein consumption) seem unlikely to materialize and may cause a considerable underestimation of agricultural land requirements.

The complexity of food security is so far not well addressed in biomass potentials and data gaps for regional break-downs, as well as trade flows, and price changes need to be closed to avoid unsustainable policy decisions based on overestimating future biomass potentials.

**Keywords:** Bioenergy, biomass potentials, food security

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## Life Cycle Thinking in Governance: The Case Study of Bioplastic Production in Thailand

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Bioeconomy is presented as a viable alternative to our fossil based economy, by switching to renewable biological resources in a wide range of economic sectors. It promotes the use of biomass not only for food, feed and energy purposes, but also for production of different bio-based materials, e.g bio-polymers. Besides the development of new conversion technologies, this will require the mobilisation of increasing amounts of biomass, triggering necessary adjustments along supply chains. A large number of actors can potentially be involved, from the stages of biomass production, extraction, processing and manufacturing up until a final product or service is created. Hence, institutional and regulatory frameworks, as well as policy and legal structures, have to be in place and enforced for the new products to deliver overall sustainability gains. A comprehensive analysis of the governance mechanisms and processes anticipated to govern emerging value chains is needed to reduce resulting systemic complexities and uncertainties.

An analytical tool is developed based on the implementation of life cycle thinking into multi-level governance approaches. The production of polylactic acid (PLA) from sugarcane in Thailand is taken as a case study, as this stands out as one of the few pathways currently carried out at commercial scale. The proposed framework consists of a) specifying the supply chain configuration and system boundaries; b) defining the inventory of stakeholders and institutions within these boundaries at the institutional, regional, and international levels. A roadmap of socio-economic actions and socio-political accounts is obtained as a result, corresponding to the interplay of structures and agents within specific contexts involved in the life cycle of PLA. Our proposed theoretical themes for analysing governance comprise structures, agents and contexts. Preliminary outcomes serve to identify significant governance gaps, mainly related to national regulations, with the risk for pushing social and environmental pressures further down the supply chain. A set of themes to reflect governance effectiveness of alternative bio-based pathways will be subsequently developed, corresponding to the impact analysis phase. In this way, this process-oriented framework for life cycle governance analysis can contribute to setting the boundaries for sustainable transformation pathways in the bioeconomy.

**Keywords:** Bioeconomy, bioplastics, governance, life cycle analysis, supply chain governance, sustainability

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## An Interdisciplinary Framework for Sustainability Assessment in the Global Bioeconomy

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A stronger reliance on the use of biological resources and processes in most, if not all, economic sectors, i.e. a bio-based transformation, is often proposed as an alternative to our current predominantly fossil resource based economies. Modern concepts of bioeconomy go far beyond bio-based energy provision and include the substitution of fossil resource based inputs to various productive sectors, such as the chemical industry and the construction sector, more efficient cascading uses of biomass, and a low bulk, but high-value biologisation of processes in food, pharmaceutical, and recycling industries among others. However, we expect sustainability outcomes of bio-based economic transformation to be context-dependent and contingent on appropriate governance measures. In this paper, we present a theory of change that identifies the main mechanisms through which bio-based transformation can translate into positive or negative outcomes in the key sustainability domains of the Sustainable Development Goals. Based on our framework we derive theoretical pathways of sustainable versus unsustainable bio-based transformation and identify related knowledge, data, and methodological gaps for future research. Using case studies from three bioeconomy sectors, we illustrate how these pathways may operate in transforming landscapes (through innovation in South American agriculture), industries (through innovation a value chains), and societies, for example, by changing production and consumption behaviour. Furthermore, we discuss the implications of the previously described transformative pathways for sustainability governance and argue that sustainable bio-based transformation requires a mix of strategies including governance for transformation, governance of transformation, and transformation of governance. We conclude with directions for future research on the sustainability of bio-based transformation.

**Keywords:** Bioeconomy, impact assessment, sustainability, theory of change

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## Plant Species Richness and Diversity in Urban Uganda: An Inventory of Kampala's Homegardens

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Urban homegardens can be considered as multifunctional biodiversity hotspots in an urbanising world and provide urban populations, including those in Kampala, Uganda, with valuable produce for home consumption and sale. However, biodiversity of urban gardens is rarely documented and their true potential for livelihoods is still poorly understood, while the whole urban homegarden system might be under threat. The aim of this study was to determine plant species composition and diversity in inner-, outer- and peri-urban gardens in Kampala, Uganda. We performed a full floristic inventory of 74 homegardens, which were visited between February and April 2015. For each plant species, apart from weeds, the scientific name, abundances and main uses were recorded. Diversity indices and summed dominance ratios (SDRs) were calculated and data analysed by applying ANOVAs, correlation and cluster analyses. The total number of plant species inventoried was 248, of which 70 plant species were food plants, 101 medicinal, 53 technical and 24 ornamental plant species. Median species richness was 25.5 (range 11 to 65) with no difference among the three studied zones. However, garden size was positively correlated with plant species richness ( $r=0.507$ ;  $p < 0.001$ ). Mean Shannon Wiener ( $H'$ ) index per garden was 2.37, with significantly lower diversity in the inner than the outer urban areas (2.65 versus 2.16;  $p = 0.011$ ). No differences between the different urban areas were found for Evenness ( $J'$ ) (mean  $J'=0.78$ ). Median plant individual density per 1000 m<sup>2</sup> garden area was 390 (range 36–3879), however, no significant differences were found between the three urban areas. The summed dominance ratio (SDR) of plant species indicated that food plants were slightly less dominant in peri-urban areas than in inner and outer urban areas (62 % versus 71 %). This difference was mainly due to a lower proportion of vegetable plant species in the peri-urban areas (18 % versus 32 %). Further data analyses, including clustering, are still on-going and final results will be presented at the conference. Outcomes of our study may be used to identify potentials for improving food production in homegardens by making better use of the available plant diversity.

**Keywords:** Floristic diversity, Shannon index, urban biodiversity

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## Population Structure and Tree Densities of Baobab (*Adansonia digitata* L.) in Kilifi County, Kenya

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The baobab tree (*Adansonia digitata* L.), which is native in semi-arid habitats of sub-Saharan Africa including Kenya, is harvested by local communities mainly for its highly nutritious fruits. Baobab raw and processed products are important for rural livelihoods as they contribute both to nutrition security and cash income generation, particularly of women. Growing demand for the fruit pulp at local and international markets may pose a threat to the natural resource base as baobab is only collected from wild trees occurring on farms and community land. However, little is known on the health of baobab populations in Kenya. Within the larger frame of the BMEL-funded BAOFOOD project, we are assessing baobab populations in randomly selected plots of 0.5 x 3 km each along a transect covering both high and low baobab density areas in Kilifi County at Kenya coast. In each of the plots, all baobab trees were documented, their height estimated and their diameter at breast height (DBH) measured. Densities of young (DBH < 1 m) and mature (DBH > 1 m) baobabs were calculated and size class distribution curves developed to assess the health of the surveyed population. First results of measuring 265 trees in three plots show a relatively high baobab density of up to 0.79 trees per hectare, but this was mainly due to the high number of mature trees, while young trees were rare (200 and 65, respectively). DBH ranged from 0.16 to 4.97 m and tree height from 1.2 to 24.0 m. A lack of young trees was found in the size class distribution curves as only 24 % of the documented trees had a DBH of < 100 cm, 51 % of 100–199 cm and 25 % of ≥ 200 cm. The lack of rejuvenation may lead to an instable population of the surveyed region, but more data from the remaining plots need to be included into the analyses and reasons for observed differences in proportions of young trees among plots identified. Our study may help to develop recommendations for sustainable resource management which is a prerequisite for enhanced utilisation of baobab in the region.

**Keywords:** Diameter at breast height, fruit, natural resource management, rejuvenation, tree densities

## Assessing Functional Biodiversity in (Sub-)Tropical Agricultural Landscapes: Lessons from South Africa's Vhembe Biosphere Reserve

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Interactive effects of climate change and land-use change may threaten food security due to trade-offs between provisioning ecosystem services (ESs) such as food and feed, and other ESs linked to functional biodiversity, such as natural pest control. Although recent developments in trait-based ecology suggest that it would be possible to adapt agricultural landscapes to meet both goals of biodiversity conservation and food security, these ideas have rarely been tested in real-world systems in the (sub-)tropics. It also remains an open question whether the functional biodiversity of higher trophic levels can be predicted by proxies of structural and functional biodiversity of vegetation. Taking two agricultural landscapes in South Africa's Vhembe Biosphere Reserve as an example, we aim to fill these research gaps.

In each agriculture landscape, settlement areas of agro-pastoralists are surrounded by croplands and near-natural habitats. These three land-use types are featured by different structural and functional characteristics of vegetation, and thus form diverging habitats for animals. We assessed these vegetation characteristics and linked them to data on the functional diversity in a variety of animal taxa such as ants, spiders, bats, and small carnivores. In this way, we were able to unravel the factors contributing to observed variation in animal biodiversity. Our findings can also contribute to the conservation of important biodiversity reservoirs in Africa's agricultural landscapes to meet both goals of biodiversity conservation and food security. Data analysis is currently in progress, but by the time of this symposium, we will be able to present first results.

**Keywords:** Biosphere reserve, ecosystem multifunctionality, plant functional types, savannah, trophic interactions

# Plants and soil

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1) Soil and soil fertility	119
2) Fertilisers	147
3) Production systems	175
4) Crop genetic resources and abiotic stress	199

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# Soil and soil fertility

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## Oral Presentations

- JOSEPH OSAFO EDUAH, HENRIK BREUNING-MADSEN, MARK ABEKOE, MATHIAS NEUMANN ANDERSEN:  
**Phosphorus Fractionation and Sorption Characteristics of Biochar Amended Soils of Ghana** 122
- STEFFEN WERNER, EDMUND KYEI AKOTO-DANSO, DELPHINE MANKA'ABUSI, CHRISTOPH STEINER, VOLKER HÄRING, ANDREAS BUERKERT, BERND MARSCHNER:  
**Nutrient Leaching in Urban Agriculture, Effects of Waste Water Irrigation and Biochar Application to a Petroplinthic Cambisol in N-Ghana** 123
- IRABELLA THIEMANN, EVA LEHNDORFF, WULF AMELUNG, JAN SIEMENS:  
**Preferential Flow Paths in Rice Systems as Hot Spots for Nutrient Cycling** 124
- RONG LANG, SERGEY BLAGODATSKIY, STEFANIE GOLDBERG, JIANCHU XU, GEORG CADISCH:  
**Rubber Cultivation Weakened the Soil Methane Sink Function Compared to Natural Forest** 125
- NIKOLA TEUTSCHEROVÁ, EDUARDO VAZQUEZ, ASHLY AREVALO, YAMILETH CHAGÜEZÁ, ENNA DÍAZ, MARTA BENITO, JACOBO ARANGO, MIRJAM PULLEMAN:  
**Is There a Link Between Biological Nitrification Inhibition and Mycorrhizal Symbiosis in *Brachiaria* Grasses?** 126

## Posters

- FLORIAN WICHERN, MD. RAFIQUL ISLAM, CONOR WATSON:  
**Salinity Effects on Short-Term Carbon and Nitrogen Mineralisation and Soil Microbial Properties in a Paddy Rice Soil under Aerobic and Anaerobic Conditions** 127
- NURUDEEN ABDUL RAHMAN, ASAMOAH LARBI, BEKELE HUNDIE KOTU, ANDREWS OPOKU, FRANCIS MARTHY TETTEH, IRMGARD HOESCHLE-ZELEDON:  
**Livestock Corralling, Plant Density and N Fertiliser Effects on Soil, Weed, Maize Yield and Income** 128



- MILKA KIBOI, FELIX NGETICH, DANIEL MUGENDI, ANNE MURIUKI, NOAH ADAMTEY, ANDREAS FLIESSBACH:  
**Potential of Soil Fertility Management Techniques on Agricultural Productivity in Tharaka-Nithi and Murang'a Counties, Kenya** 129
- EMILY WEBSTER, AMÉLIE GAUDIN, MIRJAM PULLEMAN, PABLO SILES, STEVEN FONTE:  
**Establishment of Silvopastoral Systems Supports Early Indicators of Soil Restoration in Low-Input Agroecosystems of Nicaragua** 130
- EMMANUEL AMOAKWAH, EMMANUEL ARTHUR, MATHIAS NEUMANN ANDERSEN, RAFIQ KHANDAKAR ISLAM, KWAME AGYEI FRIMPONG:  
**Corn Cob Biochar Improves Aggregate Characteristics of a Tropical Sandy Loam** 131
- IVONNE KAMPERMANN, CARSTEN MAROHN, PABLO SILES, MIRJAM PULLEMAN, GEORG CADISCH:  
**N<sub>2</sub>-Fixation and Water Stress in Beans in Agroforestry or Slash & Mulch Systems in Nicaragua** 132
- HYCENTH TIM NDAH, GÖTZ UCKERT, JOHANNES SCHULER, SARA KAWEESA, LORENZ PROBST, PETER KURIA, SAIDI MKOMWA, PAULO RODRIGUES, JOANA SOUSA, GOTTLIEB BASCH:  
**Feeding the Soil and Feeding the Cow – Conservation Agriculture in Kenya** 133
- GODFREY NAMBAFU, ANNA ADAM, ENOS ONYUKA, HOLGER BESSLER, DARIUS O. ANDIKA, SAMUEL MWONGA, JOSEPH PATRICK GWEYI-ONYANGO, CHRISTOF ENGELS:  
**Nutrient Fluxes from Soil to Market in African Indigenous Vegetables Production System** 134
- ISAAC BALUME, CARSTEN MAROHN, GENEROSE NZIGUHEBA, FRANK RASCHE:  
**Soil Fertility Variability Influenced by Resource Endowment and Farmer Knowledge in Smallholder Farming Systems of DR Congo** 135
- ALENA RABITZ, ALEXANDER HOLLAUS, TIEN DUC PHAM, BINH MINH TU, SOPHIE ZECHMEISTER-BOLTENSTERN, AXEL MENTLER:  
**Soil Fertility and Agricultural Sustainability Strategies in the Desertified Area of Binh Thuan, Vietnam** 136

EDUARDO VAZQUEZ, NIKOLA TEUTSCHEROVÁ, YAMILETH CHAGÜEZÁ, CÉSAR BOTERO, MARTA BENITO, JHON FREDDY GUTIERREZ SOLIS, MAURICIO EFREN SOTELO CABRERA, JACOBO ARANGO, MIRJAM PULLEMAN: <b>Soil Macrofauna as Indicator of Soil Quality in Improved (Silvo-)Pastoral Systems in the Tropics</b>	137
SAHRAH FISCHER, THOMAS HILGER, SEBASTIAN POCHERT, JULIUS TWINAMASIKO, JAN WELSCH, CATHERINE MEYER, ANN-KATHRIN HEHL, KATHINKA LANG, JAKOB HENI, GEORG CADISCH: <b>Saving Mt. Elgon's Soils – How Relevant Is Farmers' Knowledge in a Rapidly Changing Environment?</b>	138
CLAUDIA SCHEPP, BERND DIEKKRÜGER, MATHIAS BECKER, CONSTANZE LEEMHUIS: <b>Slope-Valley Bottom Water and Nutrient Fluxes in an Inland Valley Wetland in Uganda</b>	139
ATHENA BIRKENBERG, SIGRUN WAGNER, THOMAS HILGER, PETER LÄDERACH, REGINA BIRNER: <b>Offsetting Emissions through On-Site Carbon Accounting in Agroforestry: The Case of Carbon Neutral Certified Coffee</b>	140
HANNES KARWAT, KONRAD EGENOLF, JACOBO ARANGO, JONATHAN NUÑEZ, DANILO MORETA, IDUPULAPATI RAO, FRANK RASCHE, GEORG CADISCH: <b><math>\delta^{15}\text{N}</math> Leaf Signature in <i>Brachiaria humidicola</i> Reflects the Potential Biological Nitrification Inhibition (BNI)</b>	141
DELPHINE MANKA'ABUSI, VOLKER HÄRING, CHRISTOPH STEINER, BERND MARSCHNER, ANDREAS BUERKERT: <b>Effects of Biochar on Gaseous Carbon and Nitrogen Losses During Composting of Farm Residues in Northern Ghana</b>	142
JULIANE DAO, DÉsirÉ JEAN-PASCAL LOMPO, KATHRIN STENCHLY, VOLKER HÄRING, ANDREAS BUERKERT: <b>Effects of Gypsum on Degraded Alkaline Soils and Plant Growth in Urban Agriculture of Ouagadougou, Burkina Faso</b>	143
ALEXANDRA SANDHAGE-HOFMANN, JÖRG LÖFFLER, CHRISTIAAN C. DU PREEZ: <b>The Impact of Management Systems on Bush Encroachment and Soil Properties in Savannahs of South Africa</b>	144
RICHARD NDEMO ONWONGA, CAROLINE CHEPKOECH, R.G. WAHOME, HENNING HØGH JENSEN, BERNHARD FREYER: <b>Synchronising Legume Residue Nutrient Release with Kale (<i>Brassica oleracea</i> var. <i>acephala</i>) Uptake in a Nitisol of Kabete, Kenya</b>	145

## Phosphorus Fractionation and Sorption Characteristics of Biochar Amended Soils of Ghana

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The high phosphorus fixing capacity of tropical soils including Ghanaian soils has restrained the development of economically sustainable crop production. The application of biochar can change surface chemical properties of highly weathered tropical soils, and hence affect phosphate sorption and distribution in soils. However, little information is available on the effect of biochar at varying levels of carbonisation on the retention, bioavailability and fractions of phosphate in tropical soils of Ghana. In the present study, incubation studies were conducted for 60 days to investigate the effect and mechanism of corn cob and rice husk biochar on P sorption and fractionation in two acid and one alkaline soil. The biochars were produced at varying pyrolytic temperatures (300°C, 450°C and 650°C) and applied at a rate of 1% (w/w) to the soils. Phosphorus fractionation of biochars and soil-biochar mixtures was assessed by a modified Hedley method while sorption of P was studied by fitting the equilibrium solution and adsorbed P concentrations using Langmuir and Freundlich sorption isotherms. Amending the acid soils with biochar increased the equilibrium P concentration in solution significantly with decreasing pyrolytic temperature for the two biochar types. There was however, an increase in P sorption with increasing charring temperatures in the alkaline soil. The interaction of biochar with soils resulted in an increase in the readily available P (Resin-P & NaHCO<sub>3</sub>-Pi) making P more available for plant uptake. The increase in the readily available P pool was more significant at relatively lower temperature (300°C) than higher charring temperatures for both biochar types. Calcium-bound P (HCl<sup>-</sup>-P) of the soils increased sharply upon biochar addition but the Al & Fe-bound P (NaOH-Pi, moderately labile P) decreased. These changes suggest that the increase in P sorption in the alkaline soil with biochar addition could be due to Ca-induced P sorption or precipitation and was less affected by Fe and Al oxides. Biochar effects on soil phosphorus were aligned with characteristics of biochar and biochar-soil mixtures (PAS-FTIR, XRD etc.). The study thus showed that biochar pyrolysed at 300–450°C could be used to reduce P sorption and increase P bioavailability especially in acid soils.

**Keywords:** Acid soils, adsorption, alkaline soil, desorption, phosphorus

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## **Nutrient Leaching in Urban Agriculture, Effects of Waste Water Irrigation and Biochar Application to a Petroplinthic Cambisol in N-Ghana**

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Urban agriculture (UA) in developing countries can contribute significantly to food security and diversity. Excessive use of fertilisers, manures and waste water is well documented in the literature. This may lead to high losses of nutrients through leaching especially when irrigation exceeds the demands. Until today very little work was done to measure nutrient leaching, ways to prevent it and consequently increase nutrient use in UA. Biochar (BC) as a soil amendment received considerable attention in recent years for its potential to increase soil carbon stocks, crop yields and reduce nutrient leaching. Since production of BC is inexpensive and does not require sophisticated technology it may be a good strategy to improve soil fertility and reduce nutrient losses.

We tested the effects of biochar and waste water on nutrient losses from soil through leaching with lysimeters on a Petroplinthic Cambisol in an UA field trial in Tamale, Ghana for two years. 32 wick lysimeter were installed in Control (no amendment), Biochar (20 t ha<sup>-1</sup>), NAP (fertilisation according to normal agricultural practice) and NAP + Biochar plots. Lysimeter were sampled weekly, when irrigation or rainfall took place and total amount of leachates were recorded. The samples were analysed for NO<sub>3</sub>-N, NH<sub>4</sub>-N, PO<sub>4</sub>-P, basic cations (K, Ca, Mg, Na) and pH.

The data show a reduction of water use efficiency through waste water irrigation, which is likely attributed to soil water repellency and therefor higher conductivity. Furthermore, N loses through NO<sub>3</sub>-N leaching were found to amount to 50–100 kg ha<sup>-1</sup> per season when irrigation was appropriate. When plots were over irrigated NO<sub>3</sub>-N leaching reached up to 250 kg ha<sup>-1</sup>. BC application did not reduce leaching losses of nutrients.

**Keywords:** Biochar, nutrient leaching, urban agriculture, waste water

## Preferential Flow Paths in Rice Systems as Hot Spots for Nutrient Cycling

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After introducing upland crops like maize into permanent flooded cropping systems, soil conditions temporally change from anaerobic to aerobic. This promotes the development of desiccation cracks in the soil, which can act as preferential pathways. We analysed their role for the distribution of plant nutrients in a dye tracer experiment with Brilliant Blue on two separate fields in the International Rice Research Institute (Los Baños, Philippines). The fields were under maize-paddy rice cultivation. The dynamic of rice straw-C and fertiliser-N inside and outside the pathways was traced by applying <sup>13</sup>C-labelled rice straw and <sup>15</sup>N-labelled urea. The dye tracer was solved in the irrigation water and applied on the soil pits by a ponding pulse. The soil pits were excavated horizontally in 10 cm intervals and vertically in 5–15 cm intervals until 60 cm depth. The soil surface and profiles were photographed. Dyed and non-dyed soil samples were taken for analysis. The horizontal pictures showed decreasing areas of the dyed soil and with that decreasing proportions of the flow path areas. The typical plough pan could not be identified and it did not seem to inhibit the vertical flow of irrigation water. A direct comparison of flow paths (dyed soil samples) and bulk soil showed larger amounts of plant nutrients (C, N, Ca, K, Mg, Na) in the flow paths. The labelled straw and fertiliser could be traced down to 60 cm depth. The quantification and analysis of the microbial biomass is still in progress. Higher abundances and higher recoveries in the microbial biomass would emphasise the importance of the flow paths as important pathways for C- and N-input into the plant-soil system.

**Keywords:** <sup>13</sup>C-labelled straw, <sup>15</sup>N-labelled urea, desiccation cracks, dye tracer, flow paths, maize, paddy rice

## Rubber Cultivation Weakened the Soil Methane Sink Function Compared to Natural Forest

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The impact of transforming natural forest into rubber plantations on soil function as CH<sub>4</sub> sink has not been well understood, especially on the seasonal dynamic and changes in underlying soil processes. Aimed to understand how this land use conversion changes the soil CH<sub>4</sub> sink, we conducted measurements in both natural forests and rubber plantations in Xishuangbanna, SW China. Temporal dynamic of soil surface CH<sub>4</sub> flux, CH<sub>4</sub> concentration and isotope signature of <sup>13</sup>CH<sub>4</sub> in the soil profile at 5, 10, 30 and 70 cm depth were measured at representative time in dry and rainy season.

CH<sub>4</sub> uptake by soils in rubber plantations was only 41.8 % of uptake by forest soils, with annual CH<sub>4</sub> cumulative flux of  $-2.41 \pm 0.28$  and  $-1.01 \pm 0.23$  kg C ha<sup>-1</sup>yr<sup>-1</sup> for forests and rubber plantations respectively. The CH<sub>4</sub> oxidation was stronger in dry season than in rainy season, mainly explained by changes in soil moisture. From dry season to rainy season, CH<sub>4</sub> flux shifted to weak consumption in forest and young rubber plantation, or even towards emission in older rubber plantations; CH<sub>4</sub> concentration increased in all four depths with higher increment in older rubber plantations. The enrichment of soil CH<sub>4</sub> by <sup>13</sup>CH<sub>4</sub> was higher in forest than in rubber plantations. The decrement of delta <sup>13</sup>CH<sub>4</sub> from dry to rainy season in both land uses indicated the increased CH<sub>4</sub> production in rainy season, while the flux showed the net consumption. The CH<sub>4</sub> turnover rate suggested that the surface 0–5 cm soil was the most active layer responsible for CH<sub>4</sub> oxidation.

Conversion the forest into rubber plantation weakened soil CH<sub>4</sub> sink function. Seasonal change of CH<sub>4</sub> flux and <sup>13</sup>CH<sub>4</sub> enrichment was larger under rainforest than rubber plantations, indicating modified soil water regime under rubber. Converting forest into rubber plantations and rubber cultivation may have profound impact on greenhouse gas emission from soil.

**Keywords:** Land use change, methane sink, rubber plantation, tropical soil

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## Is There a Link between Biological Nitrification Inhibition and Mycorrhizal Symbiosis in *Brachiaria* Grasses?

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Arbuscular mycorrhizal fungi (AMF) are almost ubiquitous organisms living in symbiosis with 2/3 of vascular plants facilitating the uptake of nutrients by plants. In exchange fungi obtain their carbon from the plants. The benefits that plants obtain from the interaction between plant and fungus is believed to depend on nutrient limitations in the soil and can be regulated by the plant through modification of rhizosphere carbon (C) deposition enhancing or reducing the symbiosis. It has been proposed that nutrient stoichiometry, especially the nitrogen (N):phosphorus (P) ratio, may play a key role in AMF symbiotic functioning. The tropical grass species *Brachiaria humidicola* (Rendle) Schweick has the ability to release a substantial amount of exudates composed of substances inhibiting soil nitrification (a process known as Biological Nitrification Inhibition, BNI) which reduces N losses from soil and increases the plant nitrogen use efficiency. We hypothesise that such an advantage of high-BNI genotypes and improved N uptake could result in higher requirements of other nutrients, such as P, which may become the limiting factor for the crop growth and could lead to increased dependency on AMF symbiosis. Three *Brachiaria* genotypes differing in BNIs capacity were evaluated in a long-term field trial established at CIAT (Colombia). Root colonisation, AMF spore density and P fractions were determined before N fertilisation, one week and three weeks after ammonium sulphate application. *Brachiaria* genotypes with high-BNI capacity showed higher AMF root colonisation than low-BNI genotypes and this difference was increased after N application. Furthermore, soil P fractionation showed that the most available soil P fraction (Resin P), was lower in high BNI after N fertilisation which could indicate increased inorganic P uptake by AMF. Based on these observations, *Brachiaria* genotypes with high-BNI capacity seem to be better adapted to nutrient-poor environments coping better with both N and P limitations when compared to low-BNI cultivars. Nevertheless, the general validity of this observation needs to be confirmed based on studies in different soil types and including more *Brachiaria* genotypes. Our study provided promising insights in the role of mycorrhizal symbiosis for P uptake in relation to BNI capacity in *Brachiaria* grasses.

**Keywords:** Biological nitrification inhibition, *Brachiaria* grasses, mycorrhizal symbiosis, phosphorus

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## Salinity Effects on Short-Term Carbon and Nitrogen Mineralisation and Soil Microbial Properties in a Paddy Rice Soil under Aerobic and Anaerobic Conditions

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Bangladesh is affected by many of the challenges affecting future food production, such as a rising sea-water level leading to increased saltwater intrusion causing soil salinity. Moreover, the pronounced dry and rainy seasons lead to temporal accumulation of salts in the soils ultimately reducing plant growth. Addition of organic matter is expected to ease the effect of salinity on soil microorganisms therefore positively influencing nutrient cycling and soil fertility. However, it is not known to which extent this happens under anaerobic compared to aerobic conditions and if rice straw or manure is better suited. Therefore, the benefits of rice straw and manure addition to Bangladeshi paddy rice soils on microbial properties and nitrogen and carbon dynamics were evaluated in a short-term laboratory incubation experiment. Two different soils were incubated with rice straw, manure or a manure-rice straw mixture at 50 and 100 % water holding capacity for 27 days. Additionally, NaCl was added to half of the samples resulting in non-saline (1–1.5 dS m<sup>-1</sup>) and saline (25–29 dS m<sup>-1</sup>) conditions. Soil respiration was measured throughout the experiment. After termination, extractable C and N, inorganic N and microbial properties (microbial biomass, ergosterol, fungal, bacterial and archaeal DNA) were determined. Rice straw addition increased most microbial properties to a much greater extent than manure independent of moisture level. Salinity effects on microbial properties were strongly alleviated by rice straw and manure addition and therefore only detected in the non-amended soils. This is due to a higher availability of C for soil microorganisms after organic matter addition, which allows them to produce osmolytes, counteracting the osmotic effects of increased salinity. These results highlight the importance of organic matter addition in paddy rice soils to reduce negative effects of salinity on soil microbial communities, allowing them to maintain their main functions. Rice straw addition proved to be a valuable source of organic matter, which can counteract some of the negative effects of soil salinity. However, as rice straw is a valuable local source used also for other purposes, a combination of available organic sources might be a more economic viable option.

**Keywords:** Nutrient cycles, organic matter, residue management, salinisation, soil fertility

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## Livestock Corralling, Plant Density and N Fertiliser Effects on Soil, Weed, Maize Yield and Income

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Small scale crop-livestock farming systems dominate in West Africa. Farmers adopt different practices such as keeping animals overnight on fallow lands to deposit manure and urine (corralling), different cropping densities and apply organic and inorganic fertilisers to maximise crop yields and improve soil fertility. However, quantitative data on the interactions of these practices on crop yields, soil properties and vegetation resources is limited. A two-year study was conducted in Sudan savannah ecology of Ghana to test the hypothesis that stocking density of sheep and goat (SDSG) corralling, maize plant density (MPD) and N fertiliser rate (NFR) may increase soil quality, weed diversity, yield and net income. A split-split plot design with eight household farms as replicates was used to study the effect of three SDSG (0, 70 and 140 heads ha<sup>-1</sup>, main-plot), three MPD (66 667, 100 000 and 133 333 plants ha<sup>-1</sup>, sub-plot) and three NFR (0–40–40, 60–40–40 and 90–40–40 NPK kg ha<sup>-1</sup>, sub-sub plot). The animals were corralled from 19:00 to 06:00 hours GMT the following day with no feed and water for a period of 178 nights. The animals grazed communal pastures and crop residues during the day before corralled them at night. Increasing the SDSG corralling from 0 to 140 heads ha<sup>-1</sup> increased ( $P < 0.01$ ) soil chemical and biological properties. The SDSG affected weed species diversity with high ( $p < 0.01$ ) number of broadleaves, grasses, and sedges on plots where sheep and goat were corralled. The SDSG  $\times$  MPD and SDSG  $\times$  NFR interactions had significant on grain yield and net income. The interaction effect increased grain yield by 92 % and net income by eighteen-fold. The results suggest that maize-livestock farmers without access to mineral fertiliser could corral sheep and goats at 70 or 140 heads ha<sup>-1</sup> with maize plant density at 100 000 plants ha<sup>-1</sup> for improved grain yield and net income. Those with access to mineral fertiliser could corral sheep and goats either at 70 heads ha<sup>-1</sup> with mineral fertiliser at 90 kg N ha<sup>-1</sup> or 140 heads ha<sup>-1</sup> with mineral fertiliser at 60 kg N ha<sup>-1</sup> to increase grain yield and net income on Ferric laxisol soils of Sudan savanna zone of Ghana and similar ecologies.

**Keywords:** Fertility, interaction effect, profitability, savannah, stocking rate

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## Potential of Soil Fertility Management Techniques on Agricultural Productivity in Tharaka-Nithi and Murang'a Counties, Kenya

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Continuous cropping with low or non-use of soil external inputs is a major constraint for smallholder farmers in the highland regions of Kenya. On-station experiments were set up to determine effects of minimum (MT) and conventional (CT) tillage and organic inputs (OIs) on maize performance, water use efficiency and soil physico-chemical properties. The research was carried out in Meru South (sub-humid) and Gatanga (semi-humid) sub-counties during long rains and short rains 2016. The experimental design was a split plot and treatments laid down in a randomised complete block design with four replications per treatment. Tillage was the main plot: minimum and conventional. Soil inputs were the sub-plots; control (no input; C) mineral fertiliser (MF), crop residues (CR) + MF (RMf), CR + MF + animal manure (RMfM), CR + *Tithonia diversifolia* + Phosphate rock (RTiP), CR + animal manure+ legume intercrop (RML), CR + *Tithonia diversifolia* + animal manure (RTiM). Higher amount of rainfall was received during the long rain season than in the short rain season in both sites. Data was subjected to ANOVA using Mixed Procedure Model in SAS 9.3 software. Differences between treatment means were examined using Tukey Kramer at HSD  $p = 0.05$ . Initial soil characteristics indicated that the soils in both sites had low amounts of total nitrogen. Tillage did not have a significant effect on maize grain yield during the two cropping seasons. Nevertheless, maize grain yields were greater under minimum tillage than under conventional tillage. Compared to control, results showed that use of soil inputs significantly increased grain yields during the cropping seasons in both sites ( $p < .0001$ ). RMfM inputs led to the highest grain yields increase during LR16 season by 120 and 97 % in Meru South and Gatanga, respectively. During SR16 season, RMfM performed best in Meru South while in Gatanga Mf inputs led to the highest yields. The output highlights the importance of soil fertility management techniques to smallholder farmers and other stakeholders for better agricultural production in the highland regions.

**Keywords:** Crop yields, rainfall distribution, soil fertility

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## Establishment of Silvopastoral Systems Supports Early Indicators of Soil Restoration in Low-Input Agroecosystems of Nicaragua

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Pasture degradation hinders livestock production and ecosystem services that support rural smallholder communities throughout Latin America. Silvopastoral systems, featuring improved pasture grass species, are promising restoration strategies. However, studies evaluating the impact of such systems, in conjunction with common management practices, on indicators of soil health are lacking. We sought to evaluate the impact of low-input, improved pasture grass establishment on soil health indicators, in actively grazed silvopastoral systems. In August 2013, paired pasture management treatments (improved vs. traditional) were established on nine farms with similar management histories and edaphic characteristics in the Matagalpa department of Nicaragua. On each farm, one treatment was left as traditional pasture with naturalized grass species *Hyparrhenia rufa* while the adjacent treatment was sown with the improved *Brachiaria brizantha* cv. Marandu species and planted with tree saplings. Fertilisers were not used during this study, as such inputs are not commonly accessible for smallholders of the region. We measured a suite of soil chemical, biological, and physical variables as well as standing biomass in August 2015, two years after establishment of the trial. The improved (*B. brizantha*) pastures were found to produce more standing grass biomass and support higher levels of earthworm populations and permanganate oxidisable carbon (POXC) compared to the traditional control. Correlation analysis revealed that earthworms and POXC were associated with incipient improvements to soil aggregate stability and water holding dynamics. We report measurable improvements to soil health within just two years following the establishment of improved silvopastoral systems under common smallholder management practices and suggest that promotion of these systems, even with minimal fertility inputs, has the potential to enhance sustainability in this region.

**Keywords:** *Brachiaria brizantha* cv. Marandu, earthworms, macrofauna, pasture degradation, permanganate-oxidisable carbon (POXC), soil health

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## Corn Cob Biochar Improves Aggregate Characteristics of a Tropical Sandy Loam

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Most tropical soils are highly weathered and are vulnerable to soil erosion due to their poor aggregate characteristics. This study assessed how corn cob biochar applied at 0 [CTRL], 10 t ha<sup>-1</sup> [BC-10] and 20 t ha<sup>-1</sup>, [BC-20] and 20 t ha<sup>-1</sup> with P (P-enriched biochar) [BC-20+P] to a tropical sandy loam affected several aggregate characteristics. Soil aggregate characteristics are critical indicators of soil structural stability, and they have the propensity to influence soil physical behaviour and functioning. In this study, we investigated the effect of corn cob biochar on the aggregate characteristics of a highly weathered tropical sandy loam. Biochar was incorporated at varying rates to study its effects on the stability, strength and friability of aggregates evaluated. Biochar significantly increased soil organic carbon by 35–66% relative to the untreated soil with a surprising trend of increasing water dispersible clay as biochar rate increased. This was attributed to an increase in pH and a substantial reduction in EC following biochar incorporation. Amount of water stable aggregates was significantly improved by 27–53% in biochar treatments compared to control. Incorporation of biochar decreased the tensile strength of the large aggregates (4–8 mm and 8–16 mm), but increased same in the smaller aggregates (1–2 mm). Soil friability and workability were significantly improved in the BC-20 and BC-20+P treatments. In perspective, incorporation of biochar offers the potential to arrest the rate of degradation in highly weathered tropical soils and salvage the decline in their physical quality by minimising the effects of soil erosion.

**Keywords:** Aggregate stability, friability, tensile strength, water dispersible clay, workability

## **N<sub>2</sub>-Fixation and Water Stress in Beans in Agroforestry or Slash & Mulch Systems in Nicaragua**

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Drought and soil degradation are challenges for maize and bean agriculture production in Central America. Slash and Burn (S&B) agriculture has led to severe soil degradation and yield reduction with ongoing intensification. Two cropping systems called the Quesungual Slash & Mulch Agroforestry System (QSMAS) as well as a Slash and Mulch cropping system (S&M) were established in La Danta and La Flor in Northwestern Nicaragua, to counteract the soil degradation. The main objectives of this study were to compare water stress and nitrogen fixation capacity of bean plants (*Phaseolus vulgaris* L.) growing in these systems in the year 2015 on six farms. Statistical evaluation was made with a one-factorial ANOVA analyses and linear regressions. Water stress was determined with the <sup>13</sup>C isotope discrimination method. Nitrogen fixation was determined with the <sup>15</sup>N natural abundance method. The results revealed that under average weather conditions in La Danta, bean plants experienced less water stress in the S&M system. However, during dry conditions neither of the systems had a superior mitigation effect on the water stress. Results also showed that trees in the QSMAS were a direct competitor for the water availability to beans (i.e. negative relationship between bean <sup>13</sup>C and tree leaf biomass). However, the harvest index was significantly higher in QSMAS. The proportion of N derived from fixation was 38 % (SE 7.0) and 43 % (SE 9.8) for the QSMAS and S&M systems respectively. Nitrogen fixation was relatively low with 7.5 and 6.6 kg N ha<sup>-1</sup> for the QSMAS and S&M systems respectively, mainly due to the reduced bean growth (e.g. 379 vs 221 kg DM ha<sup>-1</sup>) associated with water stress during the later growing period.

**Keywords:** Agroforestry, drought, N fixation, stable isotopes

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## Feeding the Soil and Feeding the Cow – Conservation Agriculture in Kenya

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One of the main obstacles to the implementation of Conservation Agriculture (CA) in sub-Saharan Africa is the priority given to using crop residues as cattle feed rather than mulching material. As documented in past projects (e.g. CA-SARD, CA2Africa, ABACO), in this way the CA approach will not reach its full potential - particularly in countries with a limited biomass production due to climatic conditions. To identify pathways for enabling an implementation of CA that is not in conflict with other goals of farmers' livelihoods (e.g. livestock farming), we used a transformative learning approach with farmers and other stakeholders in Laikipia County (Kenya). The learning elements comprised: a timeline that encompasses the past promotion activities; stakeholder mapping which highlights the various stakeholders involved and their influence; non-scripted participatory videos filmed by the stakeholders themselves that show the farming system from different perspectives; focus group discussions structured by the Qualitative expert Assessment Tool for CA adoption in Africa (QAToCA). Challenges to CA adoption that were jointly identified include the competition for fodder, a lack of financial resources to get started with CA. There are knowledge gaps on proper application of CA equipment, on the fodder production and conservation options and, lastly, on sustainable crop-livestock production systems. Furthermore, farmers feel disconnected from existing governmental support. However, our findings highlight solutions which enable feeding the soil "and" feeding the cow. Some farmers already have started to grow forages on their farms in order to reduce dependence on crop residues as a feeding source – an approach which had not been promoted during past projects. This shows the importance of an enabling environment provided by government programs which supports long-term extension efforts combined with farmers' willingness to jointly learn towards a more sustainable agriculture. On farms where both systems (CA and conventional) are practised, women play an important role by experimenting with CA practices, thereby realising promising results in terms of yield and drought resilience. Furthermore, our findings underline the need for a long-term monitoring of innovation processes which is often not possible within short-term research projects and promotion programs.

**Keywords:** Adoption constraints, conservation agriculture, livelihoods, livestock

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## Nutrient Fluxes from Soil to Market in African Indigenous Vegetables Production System

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In many smallholder farming systems in sub-Saharan Africa, nutrient supply is either too low leading to soil fertility decline due to soil mining or too high leading to environmental pollution. The aim of our study was the quantification of mineral nutrient transfer from soil to market in African indigenous vegetable (AIV) production systems as guide for development of fertiliser recommendations. In a field experiment under optimal nutrient supply, we measured biomass and mineral nutrient concentrations (nitrogen, phosphorus, sulfur, potassium, magnesium, calcium) of edible (leaves, tender laterals) and non-edible (stems, coarse roots, fine roots) plant organs of six leafy vegetable species (amaranthus *Amaranthus cruentus*, cowpea *Vigna unguiculata*, African kale *Brassica carinata*, African nightshade *Solanum scabrum*, spider plant *Cleome gynandra*, common kale *Brassica oleracea acephala*). In a “batch system”, plants were completely harvested five weeks after transplanting. In a “continuous system”, plants stayed in the field for 15 weeks whereby sprouts were harvested every five weeks. Plants were harvested by pulling out or cutting five cm above soil surface or cutting edible organs only.

The nutrient transfer from soil to market was very high when plants were harvested by pulling out and largely varied among species. For example, the potassium transfer associated with the sale of 103 kg edible plant fresh mass varied between 6.3 kg for common kale and 34 kg for amaranth, the nitrogen transfer varied between 5 kg for African kale and 13.5 kg for cowpea, and the sulfur transfer varied between 1.1 kg for African nightshade and 2.3 kg for spider plant. Harvesting edible organs only, reduced the potassium transfer from soil to market between 22 % for common kale and 79 % for amaranth, the nitrogen transfer between 20 % for African kale and 69 % for cowpea, and the sulfur transfer between 13 % for common kale and 80 % for cowpea.

We conclude that due to the large differences among AIV species in biomass partitioning and nutrient concentrations in different organs, the fertiliser recommendations for replacement of nutrient transfer from soil to market need to be species-specific and must consider also the production system.

**Keywords:** Fertiliser need, harvesting technique, leafy vegetables

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## Soil Fertility Variability Influenced by Resource Endowment and Farmer Knowledge in Smallholder Farming Systems of DR Congo

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Variability in soil fertility was investigated in eastern DR Congo. Three farmers' typologies were defined based on their resource endowment (wealthy, intermediate and poor status), where land size and market access were considered as the main criteria. It was hypothesised that the level of resource endowment is reflected in soil fertility status. Hence, based on farmers' perception on soil fertility, a gradient of 96 households was investigated in four field survey implementation sites: Bushumba centre, Mulengeza, Madaka and Luduha characterized by contrasting agro-ecologies and market access. A total of 384 soil samples from randomly selected farms were collected and analysed for their major nutrients. To reduce laboratory chemical analysis, about 30% of the samples set was subjected to wet lab analysis, whereby the remainder was calculated by midMIDRIFT-PLSR based predictions. Accuracies of midMIDRIFT-PLSR based predictions across resource endowment were, on basis of the residual prediction (RPD), "acceptable" for soil total carbon ( $R^2 = 91.58$ ; RPD = 3.46), total nitrogen ( $R^2 = 85.6$ ; RPD = 2.71), and pH ( $R^2 = 88.7$ ; RPD = 3.02). The measured and predicted values were then subjected to analysis of variance using a mixed model that considered agro-ecology, typology (resource endowment), and soil depth as random terms. This statistical analysis revealed a large variability among farms in total soil C (1.13–3.33 %), total soil N (0.08–0.53 %), available soil P (0.72–97.16 mg kg<sup>-1</sup>), soil Ca (1.02–1.42 cmol(+) kg<sup>-1</sup>), and soil Mg (0.81–0.99 cmol(+) kg<sup>-1</sup>). Moreover, variability in pH (4.06–6.07) differed significantly between the studied sites (agro-ecology effect), while only exchangeable K exhibited a difference (29-870 cmol(+) kg<sup>-1</sup> with marginal farms having low extractable K content compared to fertile plots, respectively) regarding farmers' knowledge on soil fertility status. Generally, soil nutrients decreased significantly with reduced farm resource endowment with respect to land size and distance to market access which were identified as entry points to approach soil fertility improvement in the studied area. In conclusion, variability between sites, agroecology and market access provided certain evidence on the soil nutrient status serving as baseline for adequate interventions on prospective soil productivity management of smallholder farms in the studied region.

**Keywords:** Agroecology, market access, soil variability, typology classes

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## Soil Fertility and Agricultural Sustainability Strategies in the Desertified Area of Binh Thuan, Vietnam

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Land degradation caused by human impacts and climatic factors leads to desertification and results in loss of soil fertility, increased salinisation, wind and water erosion as well as a reduction of vegetation cover followed by socioeconomic problems. Furthermore, there is also an effect on the water cycle, the biogeochemical cycle and the climate. Especially land use practices like non-adjusted agricultural methods, overgrazing and degradation of the vegetation cover through deforestation are main driving forces for desertification. The present study examines how different agricultural practices in Binh Thuan province, Vietnam influence soil fertility. The region is characterised by sandy soils as well as hot and dry climate what complicates agricultural production. In order to improve soil fertility and subsequently crop yields and economic development in the coastal area sustainable management practices are needed. To evaluate which sustainability strategies are applied in the area and how peanut and dragon fruit cultivations influence soil properties, soil analyses for different soil parameters were combined with a socio-scientific survey based on quantitative interviews and SWOT analysis. Results show that most farms combine conventional farming with different sustainable agricultural practices but are threatened through local environmental conditions. Furthermore, higher amount of total organic carbon, total nitrogen as well as dissolved organic carbon directly next to the dragon fruit indicate that dragon fruit cultivation contributes more to soil fertility than peanut cultivation. This is especially through the application of mulch around the plant which increases humus content in soil and keeps the nutrients from leaching. To conclude, desertification due to human impacts and climate change is an ongoing local and global problem. For that reason, agricultural practices adapted to environmental conditions become even more important and should be accelerated even in the frame of the SDGs (Sustainable development goals).

**Keywords:** Agriculture, desertification, drylands, land degradation, soil fertility, sustainability, Vietnam

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## Soil Macrofauna as Indicator of Soil Quality in Improved (Silvo-)Pastoral Systems in the Tropics

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Silvopastoral systems (SPS) are an environmentally and economically beneficial alternative to single grass systems for livestock production. The incorporation of trees, especially legumes, in pastures has been shown to have several positive effects on soil properties and nutrient cycling, while creating a favourable microclimate for the animals and increasing the productivity (i.e. milk and meat). The inclusion of legumes or legume-trees in the pastures systems leads to improved nutrient cycling and increased biological activity creating fertility islands within the SPS. Soil macrofauna has been considered as bioindicator of soil quality because of the direct effect on soil properties and on soil organic matter fragmentation and nutrient dynamics. The present study was performed in an experimental block designed (n=3) (silvo)pastoral trial located at CIAT (Colombia) and aimed to evaluate the effect of the inclusion of the herbaceous legume (*Canavalia brasiliensis*) and both herbaceous and shrub legume (*Leucaena leucocephala*) respect to the *Brachiaria* cv. Cayman monoculture on a set of biological and physical parameters. We measured the abundance and diversity of soil macrofauna, macroaggregate morphology and soil aggregation, as well as their spatial heterogeneity in relation to the trees in the SPS. Soil samples were collected at three different distances from the *Leucaena* double-row as follows: i) between the rows, ii) at 1.5 m and iii) 5.5 m from the trees. Results obtained showed that the inclusion of legumes has a positive effect on soil macrofauna with the highest abundance found at 1.5 m distance from *Leucaena*. On the contrary, reduction of total abundance was found around the trees corresponding to higher soil compaction areas probably due to the animal grazing preference and search for shade. This phenomenon was reflected in higher proportion of physicogenic aggregates and lower amount of large water-stable macroaggregates. In addition to increased productivity of legume-based pastures and the potential to sustain higher densities of animals, our results highlight the importance of an integrated evaluation of spatial heterogeneity within SPS and discuss possible consequences for the management of trade-offs. Multivariate statistics of forthcoming data will reveal possible role of soil macrofauna as a reliable soil quality indicator.

**Keywords:** Livestock production, silvopastoral systems, soil macrofauna, soil quality indicators

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## **Saving Mt. Elgon's Soils – How Relevant Is Farmers' Knowledge in a Rapidly Changing Environment?**

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Uganda's Kapchorwa district is reportedly one of the most productive areas in the country. However, the area is heavily characterised by population pressure, strong soil nutrient depletion, erosion, and poor yields. Soil maps or recent information regarding soil degradation are not available. Local soil knowledge combined with scientific analysis may be a valuable tool for the localisation of problem areas in this region and development of mitigation strategies. Combining local soil knowledge with scientific methods increases relevance and accuracy of results as well as acceptance in local communities. Additionally, a comparison between scientific methods and local knowledge can uncover best crop management scenarios and knowledge gaps. To identify the validity of local soil knowledge for evaluating soil degradation, the following questions are examined: (i) what soil properties do local farmers use to identify soil types; (ii) how adequate are the soil properties to describe soil fertility; (iii) how adaptable are the soil properties to a rapidly changing environment.

Eight focus group discussions (FGDs) at four different altitudes on Mt. Elgon completed soil classification exercises. The FGDs also rated soil fertility and discussed best practices for management and cultivation. Additionally, 72 farmers from 35 villages participated in questionnaires about soils on their farms, and ranked their fertility. Soil samples from 135 fields were analysed for pH, plant available nitrogen (N), phosphorus (P), potassium (K), soil organic carbon (SOC), soil colour, and soil texture.

Farmers used soil colour, texture, and crop yields to classify soils. The farmers in all groups showed a very high awareness of their soils and occurring degradation. They described decreasing soil fertility with decreasing altitude. The soil analysis confirms this observation, as there is a decreasing gradient of nutrient availability with decreasing altitude. The comparison of the scientific analysis and the farmers' selected soil properties, however, showed that the properties are inadequate in identifying indicators of soil degradation. The costs and efforts of remediating a degraded soil outweigh mitigating the cause of degradation. Therefore, farmer tailored monitoring tools shall be constructed to identify early warning indicators of soil quality decrease, as well as the corresponding mitigation techniques.

**Keywords:** Degradation, local knowledge, soil colour, soil fertility, soil nutrients, texture, Uganda

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## Slope-Valley Bottom Water and Nutrient Fluxes in an Inland Valley Wetland in Uganda

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Changing rainfall patterns and reoccurring dry spells impose severe challenges on East African rainfed agricultural communities. Thus due to their prolonged plant water availability inland valley wetlands have become increasingly important for food security in the region. Yet a careful and knowledge based management is crucial for the sustainable cultivation of these fragile ecosystems. In small scale farming monetary resources for industrial fertilisers are constrained leaving nitrate as a limiting factor for crop development and making efficient management of naturally occurring nitrogen essential. This study investigates on the temporal and spatial distribution and the relocation of soil born nitrogen from the slopes to the valley bottom of an inland valley wetland in Uganda. In a plot study the effects of three land use types (bare land, semi-natural vegetation and patchy agriculture) on nitrogen content in soil and surface water is monitored using ion exchange resins and *in situ* quantification at different slope positions. Water fluxes from surface runoff and interflow are quantified on runoff plots and in excavations at the bottom of the slope. Soil moisture is measured using a PR2 soil moisture probe. Nitrogen content in soil water and soil moisture vary between the three land use types and the different slope positions, with highest concentrations found on the bare plots and at the bottom of the slope. A sandy loam layer at the bottom of the slope is delivering water and nitrate to the wetland even during dry season. Nitrate concentrations in soil water at the fringe of the wetland though were found to be very low. Thus down slope positions before the fringe seem to be of special importance if nitrate was to be put into production before being lost for plants from the wetland due to anaerobic soil conditions. This research is affiliated to the GlobE-wetlands in East Africa project.

**Keywords:** Interflow, nitrate, Uganda, wetland

## Offsetting Emissions through On-Site Carbon Accounting in Agroforestry: The Case of Carbon Neutral Certified Coffee

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Agriculture is not only affected by climate change but also contributing significantly to it; 19–24 % of greenhouse gas emissions originate from the agri-food sector. Carbon related standards and certifications such as the Publicly Available Specification (PAS) 2060 for carbon neutrality are on the rise. However, the biogenic carbon sequestration by agroforestry systems is not accounted for in such Life Cycle Assessment based certifications so far. Therefore, compensation of GHG emissions remains subject to offsetting by obtaining international carbon credits. Carbon offsetting has been often criticised for its lacking transparency and sustainability. Whereas, accounting for on-site carbon sequestration could incentivize agroforestry production systems and address consumers demand for low-carbon and sustainable agri-food products.

This study investigated the Costa Rican case of the world's first coffee that is certified as carbon neutral in compliance with PAS 2060 since 2011. The objective was to analyse the carbon sequestration potential of coffee-agroforestry-systems in Costa Rica and estimate to which extent it could compensate the coffee's carbon footprint. We developed a carbon sequestration model, with a time horizon of 20 years, based on a detailed carbon inventory in selected transects.

Carbon sequestration on average reached  $1.71 \pm 2.64 \text{ t C ha}^{-1} \text{ yr}^{-1}$ , which corresponds to findings from existing literature on coffee-agroforestry-systems in Central America. This on-site carbon sequestration rate would compensate the coffee carbon footprint of  $2.79 \text{ kg CO}_2\text{eq kg}^{-1}$  green coffee by 160 %. Factors, determining the potential of emission offsetting are: carbon sequestration  $\text{ha}^{-1}$  (most influential), yield  $\text{ha}^{-1}$  and carbon footprint of the product (least influential). The study shows the potential of accounting for on-site carbon sequestration to replace untransparent and unsustainable carbon credits. By this, it can promote agroforestry systems as a management option for farmers to tackle the multifaceted challenges today and in future.

**Keywords:** Carbon neutral, carbon sequestration, coffee agroforestry, Costa Rica

## $\delta^{15}\text{N}$ Leaf Signature in *Brachiaria humidicola* Reflects the Potential Biological Nitrification Inhibition (BNI)

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The tropical forage grass *Brachiaria humidicola* (Bh) reduces soil microbial nitrification by biological nitrification inhibition (BNI) and consequently reduces formation of nitrate ( $\text{NO}_3$ ) in soils.  $\text{NO}_3$  leaching and nitrous oxide ( $\text{N}_2\text{O}$ ) emission might therefore be reduced by BNI. Intraspecific contrasting BNI potentials in Bh have been observed but screening methods for field plots need to be further developed to identify high BNI Bh candidates. Nitrification discriminates against the stable isotope  $^{15}\text{N}$  and leads to a  $^{15}\text{N}$  enriched ammonium ( $\text{NH}_4^+$ ) and a  $^{15}\text{N}$  depleted  $\text{NO}_3$  pool. It was hypothesised that high BNI Bh genotypes would mainly feed on  $\text{NH}_4^+$  and lower  $\delta^{15}\text{N}$  values in leaves are expected whereas low BNI (and high nitrification) should cause respective higher  $\delta^{15}\text{N}$  leaf signatures under the assumption that  $\text{NO}_3$  has been leached out of the rooting zone. Contrasting BNI genotypes were grown in the Llanos of Colombia for 3 years. Plots were split and either fertilised (+N) or not (-N) with  $70 \text{ kg N ha}^{-1}$ . Soil was collected and incubated for potential nitrification determination. Leaves were collected from both split plots of two high BNI (CIAT 679 and CIAT 16888) and one low BNI (CIAT 26146) Bh hybrid frequently after fertilisation and  $^{15}\text{N}$  was measured with an IRMS. As reference  $\text{NO}_3$  in shoots were measured simultaneously and  $\text{NO}_3$  in topsoil determined at 8 DAF. A strong correlation ( $p = 0.006$ ,  $R^2=0.38$ ) was observed between means of  $\delta^{15}\text{N}$  leaf values and soil  $\text{NO}_3$  at 8 DAF. High BNI Bh showed respective lower  $\delta^{15}\text{N}$  signatures and less  $\text{NO}_3$  in stems compared to the low BNI Bh at 11 DAF. Soil incubation indicated lower nitrification for high BNI genotypes compared to the low BNI Bh. It could be demonstrated that  $\delta^{15}\text{N}$  leaf signatures and BNI are strongly linked. However it needs to be considered that the leaf  $\delta^{15}\text{N}$  might also be influenced by other factors such as N fractionation under high N availability or uptake of both N forms from soil N min pools with different  $\delta^{15}\text{N}$  values. It was concluded that the technique has the potential to screen for contrasting BNI genotypes within Bh.

**Keywords:** Isotope discrimination, N assimilation, N uptake, nitrate leaching, soil incubation

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## Effects of Biochar on Gaseous Carbon and Nitrogen Losses During Composting of Farm Residues in Northern Ghana

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Adding biochar to nutrient rich organic matter during composting reportedly reduces nitrogen (N) volatilisation and carbonisation of feedstock stabilises organic carbon (C). A biochar-compost may thus foster lasting soil organic matter build-up while providing nutrients to crops. We studied the effects of biochar, produced from on-farm waste materials as compost additives on gaseous C and N fluxes under the Sudanian conditions of northern Ghana. Three biochar types (corn cobs, cCC; rice husks, cRH; and wood, cWO) and their uncharred feedstocks (CC, RH and WO), were co-composted with poultry manure (15 vol-%) and rice husk straw (60 vol-%) in randomly allocated 1 m<sup>3</sup> compost bins. During 34 days of composting, emissions of C (CO<sub>2</sub>-C) and N (N<sub>2</sub>O-N and NH<sub>3</sub>-N) were measured using a closed chamber system composed of a photo-acoustic infrared gas analyser (INNOVA 1312-5). Biochar amended composts showed higher CO<sub>2</sub>-C emission rates during the initial composting phase. Emissions ranged from 8 to 17 g C m<sup>-2</sup> h<sup>-1</sup> in cRH, and 8 to 12 g C m<sup>-2</sup> h<sup>-1</sup> for RH. This indicated higher microbial activity in biochar treatments. Respiration significantly dropped during the later days of composting with lower emission rates in cRH (5 g C m<sup>-2</sup> h<sup>-1</sup>) and cCC (3 g C m<sup>-2</sup> h<sup>-1</sup>) compared to their un-carbonized feedstocks with 9 and 11 g C m<sup>-2</sup> h<sup>-1</sup>, respectively. Total CO<sub>2</sub>-C losses were 14 kg C m<sup>-2</sup> 34 d<sup>-1</sup> for RH and 9 kg C m<sup>-2</sup> 34 d<sup>-1</sup> for cRH resulting in a 33 % reduction ( $p < 0.05$ ). Emissions were 9 and 10 kg C m<sup>-2</sup> 34 d<sup>-1</sup> for cCC and CC while cWO and WO emitted 8 and 9 kg C m<sup>-2</sup> 34 d<sup>-1</sup>, respectively. This reduced turnover is likely a consequence of the high biochemical stability of biochar-C. Volatilisation of NH<sub>3</sub>-N was significantly lower in compost containing cWO (93 g N m<sup>-2</sup> 34 d<sup>-1</sup>) compared to WO (174 g N m<sup>-2</sup> 34 d<sup>-1</sup>), while N<sub>2</sub>O-N emissions were lower in compost mixtures containing cRH (35 %), cCC (9 %), and cWO (16 %) compared with their uncharred feedstock.

**Keywords:** Biochar-compost, carbon losses, nitrogen losses, northern Ghana

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## Effects of Gypsum on Degraded Alkaline Soils and Plant Growth in Urban Agriculture of Ouagadougou, Burkina Faso

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To meet the fresh food requirements of the rapidly increasing population of cities in the semi-arid tropics, farmers often employ low quality irrigation water. In an urban gardening area of Ouagadougou, Burkina Faso, farmers use alkaline industrial waste water since 2006 to irrigate the intensively managed fields leading to widespread salinisation. Hence, an on-farm experiment was conducted with two irrigation water qualities (clean water and wastewater) to (i) assess the effects of sodium (Na) and bicarbonate ( $\text{HCO}_3^-$ ) loaded industrial waste water on soil properties and plant development and (ii) improve the affected soil and growing conditions for plants by a gypsum ( $\text{CaSO}_4$ ) application as a soil amendment. To reach a target soil pH of 8 and an exchangeable sodium percentage (ESP) of 15 %, 6.8 and 10 t ha<sup>-1</sup> of finely powdered gypsum were incorporated into the topsoil (0–20 cm). Afterwards, rainfed maize (*Zea mays* L.) and irrigated spinach (*Spinacia oleracea* L.) were cultivated on the amended soils. Chemical and physical soil parameters, as well as plant growth, yield and nutrient contents were determined. In highly salinized field areas, gypsum application decreased soil pH on average from 8.5 to 7.2 and reduced ESP by 5.2 %. Therefore Na content in plant tissues was significantly diminished for maize (from 5.2 to 3.2 mg g<sup>-1</sup>) and for spinach (from 79.6 to 24.3 mg g<sup>-1</sup>). A decline in the soil sodium absorption rate during maize cultivation led to an increase in maize root length density in highly salinized areas by 82 %. Higher soil Ca following gypsum application also led to an increased Ca:Mg ratio from 3.5 to 7.8.

**Keywords:** Sodic soil, soil reclamation, urban agriculture, waste water irrigation

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## The Impact of Management Systems on Bush Encroachment and Soil Properties in Savannas of South Africa

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Extensive bush encroachment by *Acacia mellifera* and associated woody species are the most notable form of rangeland degradation in savannas of South Africa. Grazing and different rangeland management systems (communal and freehold) are considered to be of major importance for degradation. A vegetation change is mostly accompanied by changes in soil properties, where soils in savannah systems can profit from woody species due to litter fall, root distribution, shadow and animal resting time. We hypothesised that spatial patterns of soil properties in South Africa's rangelands are controlled by vegetation and modulated by tenure systems with higher rangeland degradation in communal areas. To test this, we sampled soils at communal and commercial land in the Kuruman area of South Africa with the following design: three farms per tenure system, 6 randomly chosen plots (100 × 100 m) per farm, and 25 soil samples (0–10 cm) per plot, each in a 5 × 5 m sampling area. At every sampling point, information of overlying vegetation was recorded. For each plot, high resolution UAV aerial photos were taken to evaluate the extent of bush encroachment. Analyses involved main physical and chemical soil parameters and isotopic analyses. The results of aerial image classification (grass, woody species, bare ground) revealed significant with higher coverage of bare ground and shrubs at communal farms, and higher grass cover at commercial farms. The tenure systems had no differences in main texture classes of the soils, but significant differences in the composition of the sand fraction, with higher levels of fine sand and lower levels of coarse sand in communal farms. The chemical soil properties showed a high variability both within and between the farms, with much higher variability within communal than commercial farms. Additionally, concentrations of nitrogen, carbon, calcium and pH were significant higher in communal farms.. Different photosynthetic pathways are responsible for differences found in <sup>13</sup>C values, with higher levels (-13‰) in C4-grassland and lower values (-22–26‰) in soils under *Acacia* (C3). We found relationships between soil properties and species or bare ground, where differences in texture likely interact with both, vegetation cover and soil properties.

**Keywords:** Bush encroachment, rangeland management, soil carbon, soil texture

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## Synchronising Legume Residue Nutrient Release with Kale (*Brassica oleracea* var. *acephala*) Uptake in a Nitisol of Kabete, Kenya

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In order to optimise the benefits of plant residue on soil quality improvement, it is critical to synchronise release of nutrients from residue decomposition with plant nutrient uptake. We assessed nutrient release rates of chickpea (*Cicer arietinum*) and white lupin (*Lupinus albus*) residues, and kale (*Brassica oleracea* var. *acephala*) nutrient uptake in a nitisol with the aim of improving synchrony. The parallel experiments; determination of kale nutrient uptake and legume residue decomposition, were carried out at the university of Nairobi field station, between November 2014 and February 2015. The residues were weighed, put in litter bags and buried at 10–15 cm soil depth. They litter bags were retrieved at 0, 15, 30, 45, 60, 75, 90, 105 and 120 days. The kale leaves were sampled at 30, 60 and 90 days after planting. The residues and kale leaves were analysed for N and P concentrations. The decay ( $Y = y_0 e^{-kt}$ ) and half-life ( $t_{1/2} = \ln(2)/k$ ) formulae were used to determine the decomposition and mineralisation rates, and time when half of the nutrients or weight is lost, respectively. The weight loss of the legume residues with incubation period (days) was rapid (0–30), moderately rapid (30–60), moderate (60–90) and gradual (90–120). The nutrient half-life for both legumes was found to be between 20 and 30 days of incubation. About 10–33, 50 and 80–86.7 % loss of N by legume residues occurred in the first 10–15, 30–60 and 120 days, respectively. About 50 % of P released occurred between 15 and 30 days for both legumes. Kale nutrient uptake was rapid (first 30 days), moderate (30 to 60 days) and gradual (between 60 and 120 days). The N and P release by chickpea and lupin, and uptake by kale intersected (i.e. point of maximum synchrony between nutrient release and uptake) at day 25 and 30, respectively. For maximum nutrient synchrony between chickpea and lupin nutrient release and kale nutrient uptake, the residues should be incorporated in soil during kale seedling (4 weeks old) transplanting to optimise on residue benefits and minimise loss of available nutrients.

**Keywords:** Chickpea, decomposition, kales, lupin, nutrient release, synchrony

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# Fertilisers

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## Oral Presentations

- OGHAIKI ASAAH NDAMBI, MARION DE VRIES:  
**Financial Incentives for Manure Management Solutions in a Peri-Urban Context** 150
- IANNA RAISSA MOREIRA DANTAS, MANFRED ZELLER, HUGO DE GROOTE, M ZACHARY GITONGA:  
**Improved Varieties of Maize and Mineral Fertiliser in Kenya: Determinants and Intensity of Use by Smallholder Farmers** 151
- CHARLES IKENNA NWANKWO, LUDGER HERRMANN, DORIS VETTERLEIN, SEBASTIAN BLASER, GÜNTER NEUMANN:  
**Seedball-Induced Changes of Root Growth and Physico-Chemical Properties in the Rhizosphere of Pearl Millet Seedlings** 152
- DEVESH SINGH, MATHIMARAN NATARAJAN, THOMAS BOLLER, ANSGAR KAHMEN:  
**Bioirrigation and Biofertilisation for Sustainable Intercropping of Pigeon Pea and Finger Millet** 153
- ROLDÁN TORRES-GUTIÉRREZ, KLEVER IVAN GRANDA MORA, BETTINA EICHLER-LOEBERMANN, JOSÉ FRANCISCO GUAMÁN DÍAZ, YELENYS ALVARADO CAPÓ:  
**Impact of Native *Rhizobium* Strains Inoculation on Local Common Bean Production at Southern Ecuador** 154

## Posters

- VONGAI CHEKANAI, REGIS CHIKOWO, KEN GILLER:  
**Nitrogen, Phosphorus and Rhizobia Inoculation Interactions on Biological Nitrogen Fixation and Nutritional Components of Common Bean (*Phaseolus vulgaris* L.)** 155
- CHARLES IKENNA NWANKWO, LUDGER HERRMANN, GÜNTER NEUMANN, ALI MAMAN AMINOU, HANNATOU MOUSSA OUMAROU, MAMAN KASSOUM NOURI, OUSMANE SY:  
**Seedball Technology Improves Pearl Millet Yield in Sahelian Production Systems** 156
- BHOOPANDER GIRI:  
**Mycorrhizal Fungus *Rhizophagus fasciculatus* Promotes Artemisinin Accumulation in *Artemisia annua*** 157

<p>AGEGNEHU SHIBABAW, GETACHEW ALEMAYEHU, ENYEW ADGO, JÖRN GERMER, FOLKARD ASCH, BERNHARD FREYER:  <b>Effect of Organic Manure and Sound Crop Rotation Pattern on Growth and Yield of Potato (<i>Solanum tuberosum</i> L.) in the High Lands of Awi Zone, Ethiopia</b></p>	158
<p>HOANG KHANH NGUYEN, ANH HUNG LE, MICHAEL BÖHME:  <b>Application of Biogas Digestate as Biofertiliser for Paddy Rice Cultivation in Southern Vietnam</b></p>	159
<p>OSMIRA FATIMA DA SILVA, ENDERSON FERREIRA, ALCIDO ELENOR WANDER:  <b>Agroeconomic Viability of Co-Inoculation in Common Beans</b></p>	160
<p>AMIT KUMAR SRIVASTAVA, CHO MILTIN MBOH, THOMAS GAISER, FRANK EWERT:  <b>Estimation of Fertiliser Use Efficiency in Current Maize Production Systems in Ethiopia</b></p>	161
<p>MORITZ NABEL, SILVIA SCHREY, VICKY TEMPERTON, ROBERT KOLLER, ULRICH SCHURR, NICOLAI JABLONOWSKI:  <b>The Importance of Organic Fertilisation and Perennial Crops for Land Degradation Neutrality</b></p>	162
<p>KANAKO SUZUKI, CHRISTIAN FATOKUN, BOUKAR OUSMANE:  <b>Increasing Cowpea Productivity Combining Rock Phosphate and Arbuscular Mycorrhizal Fungi Inoculation in Sub-Saharan Africa</b></p>	163
<p>YULDUZKHON ABDULLAEVA, DINAH NASSAL, MARIE UKSA, ELLEN KANDELER:  <b>The Effect of <i>Pseudomonas jessenii</i> RU47 on Phosphomonoesterases Activities and their Gene Abundances in the Rhizosphere of Tomato</b></p>	164
<p>EBENEZER SAM KOFI, JOSEPH KUGBE, PHILIP GHANNEY:  <b>Productive Impact of Residual Nutrients in Soybean and Maize Rotation</b></p>	165
<p>KHATEREH MOTAGHIKHA, ALI SALEHI, EHSAN KAHNEH:  <b><i>Frankia</i> inoculation: An Environmental Friendly Fertiliser of Alder Forestation</b></p>	166
<p>FELIX GRAU, TIM J. GRUNDMANN, BANDULA RANAWEERA:  <b>Development of a Growing Media for Ornamental Plants Based on Co-Composted Fecal Sludge</b></p>	167
<p>CRUZ BARRERA FREDY MAURICIO, DESIRÉE JAKOBS-SCHOENWANDT, SILKE RUPPEL, MATHIAS BECKER, BEATRICE BERGER, HELMUT JUNGE, KRISTIN DIETEL, ANANT PATEL:  <b>Compatible Solutes Accumulation Capacity of the Endophytic Bacteria <i>Kosakonia radicincitans</i></b></p>	168

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PIERRE G. TOVIHOUDI, PIERRE BIENVENU IRÉNIKATCHÉ AKPONIKPE, EULOGIE K. AGBOSSOU, CHARLES BIELDERS: <b>Understanding Variability in Maize Yield and Profitability under Fertiliser Microdosing Technology in Farmers' Fields in Northern Benin</b>	169
REINOUT IMPENS, OLIVIER DASSOU, XAVIER BONNEAU, PATRICK VAN DAMME: <b>Fertilisation of Young Oil Palms in Nigeria: Effects on Growth, Production and Profitability of Plantations</b>	170
VITALIJ DOMBINOV, SILVIA SCHREY, JOACHIM WERNER ZANG, MICHELLE WATT, NICOLAI DAVID JABLONOWSKI: <b>Does Sugarcane Bagasse Ash Modify Soybean Growth and Development?</b>	171
LAURA ARENAS, NADINE ANDRIEU, ANA MILENA OSORIO, DEISSY MARTÍNEZ, ANA MARIA LOBOGUERRERO, LILIANA PAZ, LUIS ORTEGA, SANDRA LOAIZA, NGONIDZASHE CHIRINDA: <b>Does Organic Fertilisation in the Colombian Climate Smart Village Support the Transition Towards Climate Smartness?</b>	172
ZHU YUHAO, LUTZ MERBOLD, DAVID PELSTER, EUGENIO DIAZ-PINES, KLAUS BUTTERBACH-BAHL: <b>Effect of Manure Quantity and Quality on GHG Fluxes from Tropical Pastures in Kenya</b>	173
FELIX GRAU, A.W.S. PUSHPAKUMARA, W.J.S.K. WEERAK- KODY, BANDULA RANAWEEERA, K.H.M.I. KARUNARATHNE, NILS BORCHARD: <b>Fecal Sludge Co-Compost Fertiliser for Vegetable Production under Water Stress Conditions</b>	174

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## Financial Incentives for Manure Management Solutions in a Peri-Urban Context

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In the peri-urban context of West-Java, Indonesia, manure is often discharged from dairy farms without future use. A survey of 300 dairy farmers in the district of Lembang, West Java, showed that 84 % of farmers discharged at least part of their manure directly into the environment. These practices lead to local nuisance, losses of valuable nutrients, eutrophication of water bodies, and higher greenhouse gas emissions. On the contrary, proper manure management practices involving collection, treatment, storage and application of manure as a fertiliser are known to be beneficial to the environment and to farmers. It is therefore worthy to encourage farmers to collect manure for application as a fertiliser on land used for fodder or food production.

This study analyses the costs and benefits of various manure management options which are already applied by a few farmers or are applicable under the current socio-economic situation in West Java. Data were collected on 50 dairy farms in 2016 in Lembang, West-Java. Three manure management options were analysed in terms of costs and benefits, where the farmer 1) applies manure to his own farmland without processing 2) sells or applies bio-slurry on his farm after using manure in a bio-digester and 3) sells the manure to a collector who processes it to compost and then sells it to large scale farmers.

Results showed that all manure management options were profitable. Applying manure on own farm appeared more beneficial than selling it. A farm with 2 cows would have about 20 times more benefit from fresh manure when he applies it as an organic fertiliser on his own farm rather than selling it. Profitability of manure management increased with herd size and farmers could be encouraged to manage manure together to increase profitability. Investing into manure collection, composting and selling to large scale farmers is a profitable option. Obtaining a bank loan would facilitate such an investment and in this case, the option would still be profitable on a five year loan at 10 % interest rate pa.

The Sustainable Intensification of Dairy Production in Indonesia (SIDPI) project was implemented as part of the CGIAR Research Program on Climate Change, Agriculture and Food Security (CCAFS) and with support from the government of The Netherlands. CCAFS is carried out with support from CGIAR Fund Donors and through bilateral funding agreements. For details please visit <https://ccafs.cgiar.org/donors>. The views expressed in this document cannot be taken to reflect the official opinions of these organisations.

**Keywords:** Cost benefit analysis, incentives, Indonesia, manure management, organic fertiliser

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## Improved Varieties of Maize and Mineral Fertiliser in Kenya: Determinants and Intensity of Use by Smallholder Farmers

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Kenya relies on agriculture as main source of livelihood, being responsible for 26 percent of the national gross domestic product (GDP) and supplying 75 percent of the population with jobs. Maize (*Zea mays*) is the foremost staple food crop in Kenya. In the past decades, growth in population and domestic consumption of maize grew faster than the growth in production, the latter being restricted as the arable area in Kenya can no longer be extended. Therefore, improving national food security can only be met by increasing maize yields, and a dominant strategy in Kenya was to support smallholder farmers to grow a higher share of improved varieties of maize and to increase their use of mineral fertiliser, especially in conjunction with higher-yielding hybrid maize varieties.

This paper uses a national representative survey data from maize-producing households in Kenya collected by CIMMYT between December 2012 and February 2013, referring to the 2012 cropping year. We first perform a descriptive statistical analysis of the adoption rate and use intensity for improved maize varieties and mineral fertiliser. Preliminary results show 59.5% of mineral fertiliser adoption and 79.5% of improved maize seeds adoption among the 1230 households analyzed, within the six agroecological zones of maize in Kenya. In the second part of the paper, we analyse the determinants of adoption and use intensity through a bivariate probit and bivariate censored tobit model respectively. Lastly, along with an extensive literature review on the adoption of agricultural technologies, this paper draws conclusions with implications for research and policy.

**Keywords:** Kenya, maize, mineral fertiliser, smallholder farmers, technology adoption

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## Seedball-Induced Changes of Root Growth and Physico-Chemical Properties in the Rhizosphere of Pearl Millet Seedlings

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Seedball technology is a cheap “seed-pelleting-technique” that combines 80 g sand, 50 g loam, 25ml water, 2.5 g seeds and 1 g NPK-mineral-fertiliser to produce about ten seed-containing-balls of 1.5–2.0 cm diameter size to enhance pearl millet seedlings establishment. Despite its significance for seedling improvement, little is known about early root-development and nutrient-dynamics in the root-zone, influenced by root activity. Therefore, our major objective was a non-destructive monitoring of nutrient-distribution and early root-development in seedball-derived pearl millet seedlings (one seedling/tube) using a computer-tomography (CT) assisted-scanner (XT H 225; NikonR Alzenau, Germany) with a micro-focus X-ray tube and suction-cup methods. Measurements were conducted at three time intervals at 7, 14 and 21 days after planting (DAP). Three treatments comprising non-coated seeds (control), nutrient-free seedballs (SB) and NPK–seedball (SB+NPK) were used to germinate and grow seedlings in cylinder tubes (height: 25 cm, diameter: 7 cm) for 24 days under controlled growth-chamber conditions (temperature: 30°C, humidity: 65 %, light: 12 h light, 300 $\mu$ mol m<sup>2</sup>/s ) in a completely randomised design of six treatment repetitions on a sandy soil (pH CaCl<sub>2</sub>: 4.5, >90 % sand, P-Bray: 33.2 mg kg<sup>-1</sup>). A soil moisture content of 16 % (w/w) was adjusted gravimetrically every 24<sup>th</sup> h. Suction cups ([www.rhizosphere.com](http://www.rhizosphere.com)) were used for sampling of soil solutions from the upper 3.5 cm soil layer (seedball location) and lower (7.0 cm) parts of the growth-tubes. Root dry-matter increments by 30 %, and shoot biomass and shoot dry-matter by 164 % and 225 % in SB+NPK compared to non-coated-seed control and by 60 % and 57 % compared with the nutrient-free SB variant were observed. The X-ray CT-scanning images revealed more intense development at the upper layer in the SB+NPK treatments detectable within the first 14 DAP which may reflect the well-documented root-attracting properties of localised N and P supply. The P concentration in the soil solution collected from SB+NPK root-zone was significantly 954,999 % and 4,049 % higher than in the non-coated-seed control and the SB variant, respectively. This was associated with 10 % and 48 % increase of electrical conductivity (EC), respectively. EC and P determined in the sampling-solutions declined with time, reflecting root uptake and/or translocation of nutrients into deeper soil layers.

**Keywords:** Arid/semi-arid seedlings, local materials, pearl millet roots, rhizosphere dynamics, seedball technology, seedlings establishment

## Bioirrigation and Biofertilisation for Sustainable Intercropping of Pigeon Pea and Finger Millet

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Food security for growing population and achieving the zero hunger target by 2050 is a major challenge for humanity. Sustainable intensification of agriculture, i.e. increased food production without causing environmental damage has been foreseen as the way forward to address this challenge. In this study we propose a sustainable cereal - legume intercropping model based on “bioirrigation” and biofertilisation. “Bioirrigation” is based on the principle of hydraulic lift (HL) where transfer of water occurs through roots from wet soil layers to dry soil layers as a consequence of a soil water potential gradient. Specifically, the process of bioirrigation describes the water supply of a deep-rooted plant to a neighbouring shallow-rooted plant. We conducted pot and field experiments to test whether the deep rooted pigeon pea could potentially “bioirrigate” the neighbouring finger millet via the arbuscular mycorrhizal fungi (AMF) and the plant-growth promoting rhizobacteria (PGPR). The results of our study shows that pigeon pea does perform hydraulic lift and biofertilisers (AMF + PGPR) seems to play an important role in redistributing the hydraulically lifted water to finger millet. Planting one row of pigeon pea flanking eight rows of finger millet (2:8 system) showed improved yield of finger millet compared to pigeon pea plants planted in between eight rows of finger millet plants in a mosaic fashion. We envision that sustainable intercropping on the basis of our bioirrigation and biofertilisation model will help to design appropriate intercropping system especially in rain-fed areas that could provide sustainable food security, particularly for the marginal farmers in arid and semi-arid tropics.

**Keywords:** Arbuscular mycorrhizal fungi, biofertiliser, bioirrigation, intercropping, plant growth promoting rhizobacteria, sustainable agriculture

## Impact of Native *Rhizobium* Strains Inoculation on Local Common Bean Production at Southern Ecuador

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Common bean (*Phaseolus vulgaris*) has been a staple for the majority of low income families in Ecuador. Seeking the increasing of production of this important crop through sustainable methods, our research aimed to assess the effect of native *Rhizobium* strains inoculation on nodulation, plant biomass and yields of two local genotypes at southern region of Ecuador. Seeds of Calima and Mantequilla genotypes were planted under field conditions in clay loam soil. A total of four native *Rhizobium* strains isolated from common beans were compared with the inoculation of a wild type strain (*Rhizobium etli* CNPAF512), the application of urea and a control without inoculation and fertilisation. Nodule number, shoot and root dry weight yield parameters and yields of both genotypes were assessed. The results for nodules number showed that all the strains differed statistically with control and fertilisation treatments. Although there were no differences among strains, *Rhizobium leguminosarum* bv. *viciae* (COL6) for Calima and wild type strain for Mantequilla turned out the highest values. The plant biomass was variable for both genotypes, however it was remarkable affected by isolate COL6 and urea application for Calima and *Rhizobium mesoamericanum* (NAM1) for Mantequilla. All yields components were also stimulated by the inoculation of the isolate COL6, highlighting the high performance of the strain. Surprisingly, the inoculation of the strain PIN1 (*R. etli*), the same species than wild type strain, evidenced a negative effect on most of the parameters evaluated, suggesting the specific effect of each strains for the enhancement of plan parameters and not the effect of the *Rhizobium* species. The final yields of beans were concomitant with the previous results. The inoculation of NAM1-*Rhizobium mesoamericanum* (1.58 t ha<sup>-1</sup> in Calima) and COL6- *Rhizobium leguminosarum* bv. *viciae* (1.70 t ha<sup>-1</sup> in Mantequilla), raised the best statistical results without difference with the application of nitrogen fertiliser. However, the increasing in both case comparing with the fertilisation treatment turned out of 2.53 % and 2.35 % respectively. These results clarify the genotypical variability among *Rhizobium* strains and genotypes for common bean production and to contribute to carry out a sustainable agricultural process in Andean region.

**Keywords:** Isolates, *Phaseolus vulgaris*, *Rhizobium*, sustainability, yield

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## Nitrogen, Phosphorus and Rhizobia Inoculation Interactions on Biological Nitrogen Fixation and Nutritional Components of Common Bean (*Phaseolus vulgaris* L.)

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Common bean is an important legume for improving soil fertility through biological nitrogen fixation and also good supply of protein and micronutrients for sub-Saharan Africa populations. On-farm experiments were carried out in eastern Zimbabwe to investigate the influence of nitrogen, phosphorus and rhizobia inoculation on the biological nitrogen fixation, protein, anti-nutritional factors and micronutrient content in common bean. Rhizobia inoculation, nitrogen and phosphorus were tested on two varieties (Gloria and NUA45), in a split-plot arranged in randomised complete block design. The main plot factor was the combination of N (0 and 40 kg ha<sup>-1</sup>) and P (0 and 20 kg ha<sup>-1</sup>), and the sub-plot factors were variety and inoculation (+/- inoculum (I)). Both N and P were applied at 20 kg ha<sup>-1</sup> at planting, with an additional 40 kg N ha<sup>-1</sup> top dressing (split applied) at flowering. At peak flowering, nitrogen fixation was estimated using the <sup>15</sup>N natural abundance method for the control, N, P, NP, I and NPI treatments. Using *Bidens pilosa* as the reference plant, the proportion of nitrogen fixed was not significantly different between treatments presenting a non-response of common bean to rhizobia inoculation, N and P. Common bean grain was analysed for protein, trypsin, phytate, iron, zinc, manganese, copper and boron in response to N and P fertilisers. Nitrogen and phosphorus application had no influence on protein, trypsin and phytate but increased manganese and zinc content. Simultaneously, a dilution effect was observed on the iron, boron and copper content. Farmers can apply only 20 kg ha<sup>-1</sup> P without N for increased zinc, manganese in common bean. More experiments need to be done to get a positive response of common bean to rhizobia inoculation in Zimbabwe.

**Keywords:** Biological nitrogen fixation, common bean, micronutrients, nitrogen, phosphorus, rhizobia

## Seedball Technology Improves Pearl Millet Yield in Sahelian Production Systems

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Erratic rainfall and poor soil fertility negatively affect Sahelian pearl millet cropping systems. This leads to poor seedlings establishment, and in turn low yields. Since the early growth stages are determinative for the final crop performance under Sahelian conditions, improvements should first focus on this critical early stage. However, lack of financial resources and skills disallow Sahelian farmers to adopt already existing solutions such as the application of irrigation, mineral fertiliser and seed treatments (coating and priming) to enhance seedlings establishment. Obviously, over forty years of research findings have not been extended to the Sahelian farmers. As a result, pearl millet seedlings establishment, till date, is an utmost topic in the African Sahel. In several greenhouse experiments, we chemically (nutrient concentration) and mechanically (diameter size) optimised seedball technology based on local materials, specifically for pearl millet production. Seedball is an easy and affordable “seed-pelleting” technique that combines indigenous local materials such as sand, loam, water, and seeds in a gravimetric ratio to enhance seedlings establishment. Different amendments such as fertiliser or pesticides can be added depending on target preferences and local problems e.g. seed predation. Seedballs significantly enhanced root and shoot traits compared to conventional sowing. To ascertain these findings, on-station and on-farm experiments were carried out in 2015 and 2016 planting seasons in Senegal and Niger Republic. Yield assessment revealed seedball significantly enhanced panicle production by up to 29%. Seedball yield increments vary according to soil types. No significant differences were found in on-station experiments due to over-fertilised soils. Seedball can increase yield in a typical Sahel environment. It is simple to make and cheap to acquire, it saves seeds and maximally utilises mineral fertiliser. Thus, seedball can be afforded by local farmers for pearl millet production. Additionally, it does not conflict with pre-seasonal labour loads.

**Keywords:** Local materials, local seed pelleting, smallholder farmers

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## Mycorrhizal Fungus *Rhizophagus fasciculatus* Promotes Artemisinin Accumulation in *Artemisia annua*

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Due to the development of resistance by the malaria parasite to existing anti-malarial medicines, Chinese researchers initiated a search for new antimalarial drugs and found that the endoperoxide sesquiterpene lactone - artemisinin present in the extract of *Artemisia annua* was active against chloroquine resistant forms of malaria parasite. The World Health Organisation has recommended artemisinin-based combination therapies for the treatment of *Plasmodium falciparum*-type malaria in many countries, which results in a rapid increase in annual consumption of artemisinin worldwide. Relatively low yield of artemisinin in *A. annua* is a serious constraint for the commercialisation of the artemisinin-based combination therapies; therefore, the strategies that can increase production and concentration of artemisinin in *A. annua* are urgently required to meet growing demand of artemisinin in global market. Arbuscular mycorrhizal fungi (AMF) develop symbiotic relationship with the roots of over 90 % of land plant species and have been considered key components of terrestrial ecosystems. In pursuit of understanding role of AMF, an experiment was conducted to assess the impact of *Rhizophagus fasciculatus* on the growth and concentration of artemisinin in *A. annua*. A significant increase in the biomass of *A. annua* was recorded on inoculation with AMF supplemented with P fertiliser (M+P) followed by mycorrhizal treatment alone (M). However, the biomass production was lowest in case of non-inoculated control plants. The concentrations of mineral nutrients were analysed in the leaves of *A. annua* at the end of experiment. AMF inoculation of *A. annua* alone (M) or in combination with P amendment (M+P) significantly increased the concentrations of macro- and micronutrients. In comparison to control and NM+P plants, a significant increase in the density of glandular trichome was recorded on M+P inoculation followed by M. The analysis of leaves of AMF-colonized plants exhibited higher concentration of artemisinin compared to control plants. However, maximum concentration of artemisinin was accrued on AMF inoculation in combination with P. The study revealed that AMF have a profound effect on the uptake of plant nutrients, resulting in significant increase in biomass production and accumulation of artemisinin in *A. annua* plants.

**Keywords:** Arbuscular mycorrhiza, artemisinin, mineral nutrition, nutrient acquisition, secondary metabolites

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## Effect of Organic Manure and Sound Crop Rotation Pattern on Growth and Yield of Potato (*Solanum tuberosum* L.) in the High Lands of Awi Zone, Ethiopia

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Lack of sustainable soil fertility management system is a critical challenge in the highlands of Ethiopia, wherein population and livestock pressure are high. Thus, an experiment was initiated with the objective of improving the yield of potato through organic treatments and sound crop rotation pattern. Two levels of sound crop rotation patterns and four levels of organic treatments were factorially combined and laid out in a completely randomised block design (RCBD) with four replications. The organic treatments were: V1= 0 t ha<sup>-1</sup> FYM; V2 = 5 t ha<sup>-1</sup> FYM; V3 = 2.5 t ha<sup>-1</sup> FSB; V4 = 5 t ha<sup>-1</sup> FYM +2.5 t ha<sup>-1</sup> FSB. The rotation patterns were: R1 = wheat - clover – potato and R<sup>2</sup> = clover - wheat undersown lupine – potato. In addition, farmyard manure at 1 t ha<sup>-1</sup> and wheat – fab bean – potato rotation pattern was also included as a check of farmers practice. The experimental results showed that combination of manure (5 t ha<sup>-1</sup> FYM +2.5 t ha<sup>-1</sup> FSB) with potato followed by clover and wheat rotation pattern was significantly improved the tuber yield of potato more than other treatment combinations. The total tuber yield was highest (35.15 t ha<sup>-1</sup>) compared to all other treatment combinations. In addition, the tallest plant height (86.41 cm), stem hill<sup>-1</sup> (5.26), leaf area index (4.35), medium sized tubers (17.78 t ha<sup>-1</sup>) and large sized tuber (15.50 t ha<sup>-1</sup>) were recorded on combinations of manures and potato followed by clover and wheat rotation pattern. Whereas, the lowest tuber yield of 13.02 t ha<sup>-1</sup> was recorded on unfertilised control and rotation pattern potato followed by wheat undersown lupine and clover. Hence, the annual application rate of a combination of manure (5 t ha<sup>-1</sup> FYM +2.5 t ha<sup>-1</sup> FSB) in conjunction with sound rotation pattern (potato followed by clover and wheat) could be recommended as an alternative to inorganic soil fertility management system in improving the yield and profitability of potato without remarkable achievable yield reduction.

**Keywords:** Manure, rotation pattern, soil fertility, yield

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## Application of Biogas Digestate as Biofertiliser for Paddy Rice Cultivation in Southern Vietnam

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There are different trends in agriculture, one is related towards fertiliser supply of crops and another towards reuse of organic residues. For sustainable cultivation of crops the amount of mineral fertilisers should be reduced and partly replaced with organic fertilisers. A sustainable way is the use of biogas digestate as fertiliser for paddy rice cultivation. Therefore, an experiment was designed in the Mekong delta with four mineral and organic fertiliser treatments: 1<sup>st</sup> 100 % mineral nitrogen fertiliser, 2<sup>nd</sup> 100 % digestate as biofertiliser, 3<sup>rd</sup> 50 % mineral fertiliser and 50 % biofertiliser and 4<sup>th</sup> 75 % mineral fertiliser and 25 % biofertiliser. The results show that, the parameters characterising the growth of the rice plants were not significant different. The colour of the rice plant leaves was also measured and showed significant differences between treatment 1 and 4. The plants heights of the rice plants showed no treatment effect, and were for the four treatments  $78.5 \pm 2.06$  cm,  $75.0 \pm 3.00$  cm,  $73.5 \pm 4.09$  cm and  $72.5 \pm 3.04$  cm, respectively. After harvesting, the length of the paddy rice inflorescences were measured. The differences between the variants were small and not significant, e.g. the length of the inflorescence in the 4<sup>th</sup> variant was  $17.90 \pm 1.75$  cm and in the 1<sup>st</sup> variant (control)  $20.50 \pm 1.29$  cm. The most important parameter is the grain yield that means the weight of the seeds and their quality. The highest yield was found for treatment 3 in comparison to the other treatments. It can be conclude 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 exact amount of biofertiliser, and the frequency of application are necessary.

**Keywords:** Biofertiliser, biogas plant, digestate, mineral fertiliser, nitrogen supply

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## Agroeconomic Viability of Co-Inoculation in Common Beans

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This study aimed to analyse the agroeconomic viability of the common bean cropping system using the Pérola variety, under sprinkler irrigation and co-inoculated with *Rhizobium tropici* and *Azospirillum brasilense*. It were tested seven treatments composed by different doses and forms of application that are economically feasible for the use of common bean producers in commercial and family agriculture of the Brazilian states of Goiás and Minas Gerais. The tested treatments were: control treatment (TC); nitrogen fertilised witness (TN), which received 80 kg ha<sup>-1</sup> of nitrogen (178 kg ha<sup>-1</sup> of urea); seed inoculation with two doses of *Rhizobium tropici* (Rt); inoculation of the seed with two doses of *Rhizobium tropici* plus one dose of *Azospirillum brasilense* (Rt+Ab1s); seed inoculation with two doses of *Rhizobium tropici* plus two doses of *Azospirillum brasilense* (Rt+Ab2s); seed inoculation with two doses of *Rhizobium tropici* plus spraying of two doses of *Azospirillum brasilense* (Rt+Ab2p); and inoculation of the seed with two doses of *Rhizobium tropici* plus spraying of three doses of *Azospirillum brasilense* (Rt+Ab3p). All treatments used the Perola variety. Economic viability analysis was done using partial budgeting. Partial budgets are based on the principle that small crop management changes have effects in one or more of the following areas: (1) Increase in income; (2) Reduction or elimination of costs; (3) Increase in costs; and (4) Reduction or elimination of income. The net impact of those four effects will be the positive financial changes (1 + 2) minus the negative financial changes (3 + 4). A positive net indicates that farm income will increase due to the change, while a negative net indicates the change will reduce farm income. Best economic performance on commercial farms was obtained with the combination of seed inoculation with two doses of *Rhizobium tropici* and then receiving three doses of *Azospirillum brasilense* carried out in a spray, which led to greater profitability, i.e. return rates of 90% in Goiás state and 114% in Minas Gerais state for commercial farming, and of 13% for family farming in Goiás state.

**Keywords:** *Azospirillum brasilense*, co-inoculation, partial budgeting, *Rhizobium tropici*

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## Estimation of Fertiliser Use Efficiency in Current Maize Production Systems in Ethiopia

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Maize provides the main calorie requirements in the Ethiopian diet and holds a key role in addressing food security issues. The prevailing agriculture production systems in the dryer regions of Ethiopia are vulnerable due to the lack of irrigation systems and large spatial and temporal variability in rainfall. The situation gets aggravated by a predominance of low-input production systems and depleted soils. Furthermore, interactions between the limiting resources water and nutrients strongly influence the efficiency with which the resources are used, the crop productivity, and the sustainability of production systems. Therefore, understanding the resource use and resource use efficiency of maize current production systems could help to identify possibilities of producing more with the available resources and to address the variability in yield and biomass production across the Agro-ecological zones (AEZs) in Ethiopia.

Agronomic fertiliser use efficiency (FUE) in producing maize grain and biomass was estimated in three AEZs comprising 40 administrative zones in Ethiopia using the crop model LINTUL5 embedded into the general modelling framework SIMPLACE (Scientific Impact Assessment and Modelling Platform for Advanced Crop and Ecosystem Management). The simulations were run using a long maturing cycle maize variety (BH660) and a medium maturing cycle maize variety (BH540) and historical weather data (2004–2010).

The highest FUE was estimated with the application of  $20 \text{ kg ha}^{-1} \text{ N} + 6.6 \text{ kg ha}^{-1} \text{ P}$  in AEZ 2 gradually decreasing with increased fertiliser application rate in AEZ 3 having lowest cumulative precipitation amount during the crop growth period. The finding in this study indicates that FUE of nitrogen fertiliser for maize grain and biomass production could be improved by adapting the application rates to the AEZ.

**Keywords:** Crop modelling, Ethiopia, fertiliser use efficiency, maize

## The Importance of Organic Fertilisation and Perennial Crops for Land Degradation Neutrality

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By 2050, agriculture needs to provide food and energy for 9 billion people. At the same time, agriculture is losing huge areas due to soil degradation. Within the UN sustainable development goals, land degradation neutrality indicates a key element to face this challenge. We propose a cropping system that aims to increase soil fertility of degraded and marginal sites and increases their potential for biomass production. For improved agricultural practice on degraded and marginal soils, we combine perennial biomass crops, legume intercropping and organic fertilisation. Following the idea of a closed nutrient loop, we do not only reapply nutrients but also use the carbon share of the organic fertilisation as a soil amendment, increasing soil fertility over time, allowing sustainable plant biomass production.

We present results of a three-year outdoor mesocosm experiment testing the perennial energy crop *Sida hermaphrodita* grown on marginal substrate with three kinds of fertilisation (biogas digestate, mineral NPK, and unfertilised control) in combination with legume intercropping. After three years, organic fertilisation (biogas digestate) reduced the nitrate concentration in leachate and increased the soil carbon content when compared to mineral fertilisation (NPK). On marginal substrate biomass yields of *Sida* were 25 % higher when fertilised organically, compared to mineral fertiliser. Further, we show that intercropped legume *Medicago sativa* fixed large amounts of N, especially when fertilised organically, whereas mineral fertilisation suppressed biological nitrogen fixation.

We conclude that the perennial energy crop *Sida hermaphrodita* in combination with organic fertilisation and legume intercropping has great potential to increase and restore the soil fertility of degraded and marginal soils, produce substantial biomass yields and thus contribute to the goals of land degradation neutrality.

**Keywords:** Marginal and degraded land, organic fertilisation, perennial biomass crops

## Increasing Cowpea Productivity Combining Rock Phosphate and Arbuscular Mycorrhizal Fungi Inoculation in Sub-Saharan Africa

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Cowpea is a very important crop in sub-Saharan Africa (SSA) as human food due to its high protein content, quality feed for livestock, and it helps to restore soil fertility through nitrogen fixation. However, phosphorous (P) deficiency remains a serious problem to cowpea production. Our study focused on the use of indigenous rock P due to its affordability. We inoculated cowpea with *Glomus intraradices* as arbuscular mycorrhizal fungi (AMF) to promote P uptake from rock P.

Results from pot experiments using low P soil (approx. 1 ppm) from Fashola village in south-western Nigeria showed that the optimum application level of Togolese rock P is 60 mg P kg<sup>-1</sup> for cowpea cultivation.

Using 15 cowpea genotypes, the pot test was conducted for verifying the effects of co-application of rock P at 60 mg P kg<sup>-1</sup> and AMF inoculation. One of 15 genotypes (Sanzi) showed significantly ( $p < 0.05$ ) higher shoot dry weight (SDW) at 8 weeks after planting (WAP) with AMF co-application than in the treatment of only rock P application. The SDW of other 14 cowpea genotypes were slightly higher than when only rock P was applied. AMF inoculation appears to be ineffective under high soil P condition. Therefore, these results indicated that rock P application at 60 mg P kg<sup>-1</sup> is too high for AMF inoculation to work. Optimum application amount of rock P should be less than 60 mg P kg<sup>-1</sup>.

In another pot test, four levels of rock P application: 0, 20, 40, and 60 mg P kg<sup>-1</sup> were established with AMF inoculation using six cowpea genotypes selected from above mentioned nine genotypes. The SDW at 8 WAP showed that 20 mg P kg<sup>-1</sup> was the optimum level for cowpea with AMF inoculation.

Additionally, AMF can contribute to increase water as well as P uptake. We observed that AMF inoculation has positive effect on increasing drought tolerance of cowpea. More detailed studies need to be carried out to elucidate the effects of the co-application of rock P and AMF inoculation on cowpea productivity in SSA.

**Keywords:** Arbuscular mycorrhizal fungi, cowpea, rock phosphate

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## The Effect of *Pseudomonas jessenii* RU47 on Phosphomonoesterases Activities and their Gene Abundances in the Rhizosphere of Tomato

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Phosphorus (P) is a vital macronutrient for plants and microorganisms and their growth and development are often limited by the lack of P availability in the soil. Therefore, the application rate of artificial P fertilisers has been globally increased. However, excess use of P amendments causes severe environmental problems. The aim of the study was to investigate the application potential of biological alternatives such as soil inoculation with plant growth promoting bacteria (PGPB) to increase direct P mineralisation in the soil. Many soil microbes including PGPB are able to mineralise organic P to a plant-available form by excreting enzymes such as phosphomonoesterases (EC 3.1.3). This enzyme group includes acid and alkaline phosphomonoesterases, which are phylogenetically widely distributed among bacteria and encoded by the genes *PhoD* and *PhoN*, respectively.

A study was conducted in the frame of the “BIOFEKTOR” project (funded by the European Commission) in order to investigate the effect of inoculation with *Pseudomonas jessenii* RU47 and additional P fertilisation on tomato plant. Soil samples were collected from bulk soil and the rhizosphere and alkaline and acid phosphomonoesterase activities were measured. The abundance of *PhoD* and *PhoN* genes will be measured in soil metagenomic DNA with quantitative real-time PCR using degenerative primers.

The results obtained so far reveal a higher acid and alkaline phosphomonoesterase activity in the rhizosphere than in the bulk soil ( $p < 0.05$ ). Significant differences in both enzyme activities with respect to the different inoculation treatments were only recorded in the rhizosphere. Higher acid phosphomonoesterase activity was observed in bulk soil than the rhizosphere in the P unfertilised rhizoboxes. Further investigation of *PhoD* and *PhoN* gene abundance will determine whether inoculant strains or P fertilisers can increase the genetic potential for P mineralisation in the soil. Results of the study will contribute to further research in P fertiliser alternatives in order to ensure future sustainable agriculture.

**Keywords:** Acid and alkaline phosphomonoesterase, enzyme activity, microbial mineralisation, phosphorus, qPCR

## Productive Impact of Residual Nutrients in Soybean and Maize Rotation

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Poor land management has resulted in severe soil nutrient depletion in Africa. Over the years, alternative agricultural practices have been promoted to reduce the use of expensive mineral fertilisers and to restore and sustain soil fertility. This study was conducted in the Guinea savannah zone of Ghana to assess the performance of soybean and maize in a rotation system. In season one, using randomised complete block design the treatments used were untreated sole soybean, rhizobia inoculation, phosphorus application, rhizobia inoculation with phosphorus application and sole maize. In the second season, the first season experimental plots served as main plot and were divided into four sub-plots on which maize were planted and treated with four nitrogen rates (30, 60, 90 and 120 kg N ha<sup>-1</sup>) in a split plot design. Residual soil N, P and their effect on growth and yield of maize and soybean were assessed. The results show that soybean production led to significant increases in residual soil nitrogen content of about 16 kg ha<sup>-1</sup> to 55 kg ha<sup>-1</sup>, which is about 8 to 28 folds higher than that observed in maize fields. The level of N was enhanced with inoculation. The application of P to maize during the first cropping season of maize-soybean rotation led to increases in residual P levels of soils which had positive impact on yield of soybean that was grown in the second season. Grain yield of maize that followed soybean in a rotation system performed better than maize that followed maize at various fertiliser rates. Yield differences from the second season maize production in a soybean-maize rotation system was more pronounced at lower rates of inorganic N application of 30 kg/ha than in maize-maize rotation. This shows that the residual N helps maize crop when low rate of N (30 kg ha<sup>-1</sup>) is applied. The results also showed that phosphorus applied to maize in the first season enhanced the performance of sole soybean sowed in the second season. Similarly, application of 60 kg N ha<sup>-1</sup> to maize that follows soybean production in a rotation system makes much economic sense which will help the resource poor farmer.

**Keywords:** Impact, maize, nutrients, P residual, rotation, soybean

## ***Frankia* inoculation: An Environmental Friendly Fertiliser of Alder Forestation**

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Alders (*Alnus* spp.) are native trees of the Hyrcanian forests and due its fast-growing and pioneering ability it is a very important tree to restore disturbed forests as well as for timber production in North Iran. Most of the biological nitrogen fixation in the forest soil is done by Actinorhizal plants. *Frankia* symbiosis with alder tree roots plays a special role, and as a result of this coexistence, has a positive effect on tree growth. To study the effect of symbiosis of *Frankia* with tree roots of *Alnus subcordata* and *Alnus glutinosa* an experiment based on randomised complete block design was conducted under greenhouse conditions including four treatments and four replications: 1. control (soil without inoculation with *Frankia*; 2. inoculation with *Frankia*; 3. 50 kg of N fertiliser ha<sup>-1</sup>; 4. 100 kg N fertiliser ha<sup>-1</sup>. The results showed that *Frankia* inoculation in combination with N fertiliser had a significantly positive effect on the diameter and shoot dry weight of *Alnus subcordata* and *Alnus glutinosa* as compared to the control. Nodule dry weights also showed significant differences for the two inoculations (max.) and control (min.) and indicated that N fertiliser reduces nodulation on the roots of alder trees. The results showed further that overall *Frankia* activity in the soil decreased with N application. It can be concluded that *Frankia* inoculation is essential for increasing growth and mineral nutrition of *A. glutinosa* and *A. subcordata* seedlings in sustainable forestation. Thus, inoculation with *Frankia* at the earlier stage of growth or in the nursery will increase the compatibility of alder tree with their new environment.

**Keywords:** Alder trees, *Frankia* symbiosis

## Development of a Growing Media for Ornamental Plants Based on Co-Composted Fecal Sludge

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Liquid and solid waste management face severe issues in Sri Lanka. The most obvious problem is urban waste disposal. In many municipalities, waste services are restricted to collection and disposal only, whereas treatment and recycling options are hardly implemented, resulting in environmental pollution instead of resource recovery. Co-composting of dewatered fecal sludge (DFS) with organic fractions of municipal solid waste (MSW) has a high potential to be used to reduce the total amount of waste and being used as a resource for agricultural and horticultural purposes.

The possibility to substitute inorganically fertilisation by adding co-compost to a growing media for ornamental plant production was object of an experiment. Co-Compost from DFS and MSW was added to a growing media in proportions from 10 to 40 vol.-%. Additionally, these four treatments had been amended with 15 vol.-% biochar from empty fruit bunches of palm oil production. Chemical and physical parameters of the growing media as well as its effect on plant growth were tested by cultivating *Aglaonema commutata*. As control a standard growing media was used to compare the results with the general practice.

Results show that co compost is able to substitute mineral fertilisation, while enhancing structural characteristics of the growing media. Nutrient availability from co-compost was sufficient and plant quality parameters comparable to general practice, when added in medium amounts. Biochar decreased salt stress and lead to an extended availability of nitrogen. Regarding the structural effect all co-compost treatments increased water retention capacity. Furthermore, biochar increased porosity, leading to a more balanced oxygen supply to the roots.

These results indicate that co-compost together with biochar can be regarded as a value adding component to a growing media, leading to sufficient nutrient supply and enhance the structural properties. Further experiments with other crops and longer cultivation periods need to be conducted to verify these results.

**Keywords:** Fecal sludge, growing media, resource reuse



## Compatible Solutes Accumulation Capacity of the Endophytic Bacteria *Kosakonia radicincitans*

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Interest in endophytic plant growth promoting bacteria (PGPBs) has increased during the last years because they are better protected inside plant tissues from abiotic stresses such as extreme variations in temperature, pH, nutrient, and water availability as well as biotic stresses such as competition. Endophytic PGPBs can directly or indirectly facilitate the growth of plants, thus decreasing synthetic fertilisers input. Recent studies on endophytic PGPB strain *Kosakonia radicincitans* DMS 16656T isolated by IGZ demonstrated its plant hormones production, N-fixing and phosphorus solubilising capacity, besides showing a wide plant growth promotion activity. However, the drying survival of the Gram-negative cells and shelf life remains poor. As a consequence, cultivation and formulation techniques for *K. radicincitans* are highly needed. Previous studies from our working group demonstrate the benefits of osmotic stress during cultivation on cell drying survival. Here we set out to elucidate the compatible solutes accumulation capacity of *K. radicincitans* triggered by osmotic stress. A high-throughput microfermentation approach with the BioLector® yielded results indicating accumulation affinity to pyrimidines such as ectoine and hydroxyectoine and the amino acid betaine from the culture media, significantly enhancing its growth rate under osmotic stress exerted by 4 % NaCl. When these compatible solutes were added to culture media with a concentration of 1 mM, since the beginning of fermentation, lag phase was reduced down to 6.7 h in comparison to the control media, which required at least 21.6 h. These first results indicate that a systematic approach to cultivation and formulation may increase shelf life of this Gram-negative bacterium.

**Keywords:** Biofertilisation, BioLector®, cultivation, endophytic bacteria

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## Understanding Variability in Maize Yield and Profitability under Fertiliser Microdosing Technology in Farmers' Fields in Northern Benin

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Fertiliser microdosing is currently promoted in semi-arid areas of sub-Saharan Africa as a means to increase crop productivity, profitability and resource use efficiency. However, little is still known regarding the main factors that govern yield response to this technique in smallholder farmers' fields. In this study, the performance of two microdosing options applied alone [(M1, 23.8 kg N ha<sup>-1</sup>, 4.1 kg P ha<sup>-1</sup> and 7.8 kg K ha<sup>-1</sup> and M2 (33.1 kg N ha<sup>-1</sup>, 8.2 kg P ha<sup>-1</sup> and 15.6 kg K ha<sup>-1</sup>)] or combined with hill-placed manure at 3 t ha<sup>-1</sup> was evaluated on maize yield at 18 sites in 2014 and 32 sites in 2015. These four treatments were compared to an unfertilised control and broadcast recommended rate (RR, 76 kg N ha<sup>-1</sup>, 13.1 kg P ha<sup>-1</sup>, and 24.9 kg K ha<sup>-1</sup>). We observed a strong positive response for all of the sites to both M1 and M2, which significantly increased maize grain yields by 1143 and 1232 kg ha<sup>-1</sup>, respectively, compared to the unfertilised control (1069 kg ha<sup>-1</sup>). Overall, there was no significant difference in yields between microdosing alone and RR in both seasons. Combining microdosing and manure resulted in higher yield responses (by 1911 and 2066 kg ha<sup>-1</sup> for M1 and M2, respectively). There was a large variability in yields among farmers, from 512 to 1687 kg ha<sup>-1</sup>, 976 to 4006 kg ha<sup>-1</sup> and 1513 to 4733 kg ha<sup>-1</sup> for the control, unmanured and manured fertilised plots, respectively. This variability can be explained by the total rainfall, weed pressure, and the topsoil characteristics (pH, clay content, Exch-K and Mg and organic C). Applying microdosing alone or combined with manure was economically profitable for more than 80 % (VCR=2), while only 58 % achieved a VCR of 2 under the RR treatment. The results indicate that fertiliser microdosing is better adapted to the realities of smallholder farmers than the RR while still ensuring very significant yield increases and economic benefits. However, there is a need to evaluate this technology in a larger zone and number of farms to better predict crop responses and for a widespread adoption.

**Keywords:** Fertiliser microdosing, maize yield response, management and environmental factors, northern Benin, profitability

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## **Fertilisation of Young Oil Palms in Nigeria: Effects on Growth, Production and Profitability of Plantations**

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Nigeria is at the core of the oil palm belt, the African oil palm's centre of origin, where its products have been used since thousands of years. Once the largest palm oil producer it is now the 5<sup>th</sup> in the world and is importing palm oil to supply the demand from its population. This is surprising considering that Nigeria has over 3 million hectares under oil palm and that the crop can yield over 4 tons of oil per hectare per year in the region. Average yields are less than a fifth of the world average and reflect the low input and extensive way of cultivation of many plantations and producers. Oil palm plantations are usually not or inadequately fertilised, especially at the young age when investment costs are still high and production is yet to start. In any suitable environment and with high yielding planting material fertilisation represents the main yield gap for oil palm. Using the data from a 7-year trial field on a large commercial plantation in Edo state Nigeria this paper presents the effects that applications of inorganic and organic fertilisers have on the growth, production and profitability of young oil palm plantations. The treatments consist of an unfertilised control (T), company standard inorganic fertilisation regime (C1), half the standard fertilisation regime (C0.5) and exclusive organic fertilisation using Empty Fruit Bunches (E). The growth variables Collar Girth and Palm Height are consistently and significantly lower for T. The production data indicate a difference in bunch Oil Extraction Rate in favour of T but due to the stronger positive effect of fertilisation on bunch production, any application leads to significant increase in oil yield within the first 4 years of production (4<sup>th</sup> to 7<sup>th</sup> year after planting) with E giving the highest yield. When costs and benefits are added to the analysis inorganic fertilisers are more profitable because of the high application costs of organic fertiliser and their limited availability. Just 7 years after planting, applying the standard fertiliser regime already gives 15 % higher profit from the oil produced.

**Keywords:** Fertilisation, Nigeria, oil palm, profitability

## Does Sugarcane Bagasse Ash Modify Soybean Growth and Development?

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After extraction of sugarcane juice, the remaining fibrous material, so-called bagasse, is burned for energy production resulting in bagasse ash. Bagasse ash is poor in nitrogen (N) but still contains varying amounts of other plant-nutrients, including phosphorus (P) and potassium (K). In between sugarcane rotations, N-fixing cover crops like soybeans are planted to increase soil N-content and to reduce the need for subsequent N fertilisation. Since soybean does not rely on mineral N, bagasse ash has the potential of serving as a fertiliser. Here we study the bagasse ash effects on soybean growth and development.

In our analyses, soybeans inoculated with Rhizobia were cultivated under greenhouse conditions for 56 days. Nutrient poor substrates were homogeneously mixed with eight doses of bagasse ash (between 0 and 30 g ash/L substrate) and the control treatments contained identical amounts of P and K, in form of triple superphosphate and potassium sulphate, as supplied by bagasse ash. After harvesting, plant biomass was determined and stems, petioles, leaflets, pods, roots and nodules were analysed with regards to morphology and N, P and K contents.

The results show that bagasse ash P and K are less plant-available than from the traditional fertilisers. Soybeans growing on bagasse ash treated substrate responded by morphological plasticity. Furthermore, the N content of bagasse ash treated soybeans significantly decreased compared to traditional fertilisers and this was probably a result of significantly decreased nodules activity. Thus, the application of bagasse ash increased the plant biomass, modified the plant plasticity and reduced the activity of N-fixing Rhizobia.

**Keywords:** Dose-response experiment, ICP-OES analyses, nodule activity, non-invasive plant phenotyping, phosphorus and potassium plant-availabilities, plant plasticity, soybeans, sugarcane bagasse ash

## Does Organic Fertilisation in the Colombian Climate Smart Village Support the Transition Towards Climate Smartness?

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The Climate Smart Villages (CSV) represent an agriculture research-for-development approach that enables dialogue between communities of farmers, scientists, extensionists and decision-makers towards co-learning and co-developing context-specific options that support short and long-term adaptation to climate change while reducing impacts on the environment (e.g. GHG emissions) and increasing productivity (i.e., addressing all three pillars of Climate Smart Agriculture). In Colombia, 14 communities in the northwest of Popayán, the capital city of Cauca Department, started a CSV in 2014. In this CSV, farmers are growing coffee and sugarcane on small areas (< 5 ha) that are vulnerable to drought. Farmers (n=30); CCAAFS; ECOHABITATS and CIAT scientists jointly selected eight practices due to their potential to improve food security and income. Some of these practices, such as good crop residue management, potentially contribute towards climate change mitigation. Our objective was to quantify the mitigation potential of different crop fertilisation options. In 2016, we conducted field survey (n=12) to collect data on management practices. The collected data was used to model GHG balances associated with the different fertilisation practices, using the greenhouse gases calculator Cool Farm Tool (CFT). The GHG balances from different fertilisation strategies were modelled comparing two scenarios: before (i.e., chemical fertilisation) and after (i.e., composting using coffee post-harvest residues, animal manure and other domestic organic wastes) the commencement of the CSV. Results show that as a result of the CSV, 70 % of surveyed farmers had changed from chemical to organic fertilisation. Estimations showed that each 1000 kg of harvested coffee generates an average of 430 kg of post-harvest waste. Replacing chemical fertilisers with organic material, such as coffee residues, was associated with a 33 % reduction of GHG emissions. However, it is important to note that these results have high uncertainty due to large uncertainties associated with both the activity data and the Tier 1 emission factors, on which CFT is based. We conclude that organic fertilisation is a suitable strategy to mitigate GHG emissions, increase the eco-efficiency through nutrient cycling and reduce dependence on chemical fertilisers. Moreover, the multi-actor participatory process was critical for promoting the transition towards climate-smartness.

**Keywords:** Chemical fertilisation, cool farm tool, crop residues, organic fertilisation

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## Effect of Manure Quantity and Quality on GHG Fluxes from Tropical Pastures in Kenya

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Dung patches on grazed rangeland are a major source of anthropogenic GHGs emissions from agricultural systems. Dung is rich in available carbon and nitrogen, thus, supporting microbial processes such as methanogenesis, nitrification and denitrification. These processes are driving greenhouse gas emissions from dung. However, the amount and quality of dung patches depends on nutritional status and feed intake of the livestock. Factors, which so far have not been considered in most studies focusing on GHG emissions from dung. Moreover, our study focus on Kenya, a country in sub-Saharan Africa (SSA), for which little to nothing is known about regarding manure induced GHG emissions. Using an automated chamber system, we investigated the effect of manure quality and quantity on dung patches' GHG emissions in the dry and wet season. Experiments were done on the campus of the International Livestock Research Institute, Nairobi, Kenya.

While significant CH<sub>4</sub> fluxes were observed immediately following dung application to rangelands, no major stimulation of N<sub>2</sub>O and CO<sub>2</sub> fluxes were observed. However, total net GHGs cumulative emissions from 1 kg manure were twice as high as those from 0.5 kg manure during two consecutive dry seasons.

With regard to manure quality experiment, CH<sub>4</sub> emissions from farm manure dung patches were approx. one magnitude higher as from dung patches of cattle fed at 40% maintenance. However, no significant manure quality effects were found on both net cumulative CO<sub>2</sub> and N<sub>2</sub>O emissions in four observation periods. Specifically for dung patches N<sub>2</sub>O emissions showed large variations in total cumulative emissions over a four week period, which could partly be explained by variations in environmental conditions (dry/ wet season), but partly were stochastic. This suggests that more research with more replicates and treatments in different seasons is required to calculate robust emission factors for N<sub>2</sub>O emissions from dung patches from rangelands in SSA.

**Keywords:** Dung patches, GHGs emissions, manure quantity and quality, sub-Saharan Africa

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## Fecal Sludge Co-Compost Fertiliser for Vegetable Production under Water Stress Conditions

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Insufficient waste management in Sri Lanka attracted interest in alternative approaches of disposal and recycling of potentially pathogenic organic wastes. Co-composted dewatered fecal sludge (DFS) with organic fractions of municipal solid waste (MSW) is supposed to have a potential to be used as an agricultural resource. Up to now, little is known about the usage of such a co-compost fertiliser and needs to be studied in order to achieve a better understanding of plant growth and soil impact to generate knowledge and application recommendations. Thus, the aim of this study was to assess the agronomic value of composted DFS-MSW mixture (initial ratio 1:2) compared to commercial mineral fertiliser.

Field experiments were conducted with DFS-MS, its biochar enriched form and mineral fertiliser. As crops a short-term crop *Raphanus sativus* 'Beeralurabu' (Radish) and a long-term crop, *Capsicum annum* 'CA-8' (*Capsicum*) were used and cultivated for 50 and 120 days, respectively. Both field trials were established in a randomised complete block design.

Amended soils with DFS-MSW compost and biochar increased yields of *Raphanus sativus* under drought conditions related to those assessed for control plots. For *Capsicum annum*, that requires longer growth periods, yields harvested on soils with DFS-MSW were similar to those harvested on control plots while a combined application of DFS-MSW and biochar increased yields. Applied biochar increased soil pH, which likely affected availability of soil nutrients.

This study revealed comparable effect of compost DFS-MSW and its combination with biochar on plant productivity compared to commercial mineral fertilisation at field conditions.

The project is financially supported by BMZ and GIZ-BEAF.

**Keywords:** Biochar, composting, fecal sludge, horticulture, municipal solid waste, resource recovery, soil amendment

# Production systems

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## Oral Presentations

- GEORGE AYAGA, JOHN ACHIENG, JOB KIHARA, FLORA AJWERA:  
**Conservation Agriculture: A Panacea for Food Insecurity among Smallholder Farmers in East Africa** 178
- JULIET WANJIKU KAMAU, CHRISTIAN BORGEMEISTER, TILL STELLMACHER, LISA BIBER-FREUDENBERGER:  
**Characterisation of Organic and Non-Organic Smallholder Farms: A Case of Highlands and Lowlands in Kenya** 179
- LIN BAUTZE, ADRIAN MÜLLER, MATTHIAS MEIER, ANDREAS GATTINGER:  
**The Potential of Alley Cropping as a Multi-Dimensional Strategy for Climate Change Adaptation in Africa** 180
- JULIUS KWESIGA, DANIEL NEUHOFF, KALIMUTHU SENTHILKUMAR, ULRICH KÖPKE, MATHIAS BECKER:  
**On-Farm Evaluation of Yields and Yield Gaps of Rainfed Lowland Rice Using Good Agriculture Practices** 181
- OMARSHERIF MOHAMMED JEMAL, DANIEL CALLO-CONCHA, HABTAMU S. ARAGAW:  
**Contribution of Local Agroforestry Systems to Food and Nutrition Security of Small Farming Households in Yayu, Southwestern Ethiopia** 182

## Posters

- BALDUR JANZ, SEBASTIAN WELLER, DAVID KRAUS, REINER WASSMANN, KLAUS BUTTERBACH-BAHL, RALF KIESE:  
**Global Warming Potential of Diversified Tropical Rice Rotation Systems after Straw Return and Legume Intercropping** 183
- SUSANNE ZIEGLER, DANIEL NEUHOFF, KALIMUTHU SENTHILKUMAR, MAUREEN NAMUGALU, KRISTINA GROTEL-ÜSCHEN, BJÖRN GLASNER, MATHIAS BECKER, ULRICH KÖPKE:  
**Increasing Crop Productivity in Rainfed Rice Systems of Central Uganda** 184
- BERNHARD LIESE, REINER WASSMANN, MATHIAS BECKER:  
**Effects of Diversified Rice-Based System on Nutrient Balances and Yield Gaps in the Philippines** 185



- CHRISTINE KREYE, CHARLES CHIGEMEZU, EJALONIBU SHOLA, THANNI BOLAJI, REBECCA ENESI, STEFAN HAUSER, ABDULAI JALLOH, ADEYEMI OLOJEDE, OMOLARA ONASANYA, INNOCENT ONYEKWERE, PIETER PYPERS, FELIX SALAKO, MARK TOKULA, BERNARD VANLAUWE:  
**Assessing Yield Responses in Cassava - Maize Intercropping Across Diverse Environments in Southern Nigeria** 186
- RALF RATHSACK, SILKE ELWERS:  
**Smart Designed, Mechanised Large-Scale Cocoa Plantations as a Forward-Looking Component of Sustainable Cocoa Production** 187
- AYE AYE THANT, MARIE KALOUSOVÁ, HLA THAN:  
**Effects of Seed Sizes and Varieties on Growth, Yield, and Oil and Protein Contents of Groundnut (*Arachis hypogaea* L.)** 188
- RIJANTA:  
**In the Shadow of Large Infrastructure Development: Sustainability of Sawah Surjan Systems in Yogyakarta, Indonesia** 189
- PIERRE ELLSSEL, GEROLD RAHMANN, BERNHARD FREYER:  
**Evaluation of Agronomic Interventions Regarding Productivity and Profitability on Smallholder Farms with Wheat Production in Arsi, Ethiopia** 190
- CHRISTIAN BUNN, FELIX SCHREYER, FABIO CASTRO:  
**Assessing the Needs for Different Climate Change Adaptation Strategies in Ghana's Cacao Sector** 191
- CARLOS A. HOUDEGBE, E. O. DEEDI SOGBOHOSSOU, ENOCH G. ACHIGAN-DAKO:  
**Effect of Agronomic Practices on Growth and Leaf Yield in *Gynandropsis gynandra* (L.) Briq.** 192
- MONIQUE ALTMANN, RICO MÖLLER, DETHARDT GOETZE, CHRISTIANA OLUSEGUN, STEFAN POREMBSKI, KATHARINA STEIN:  
**Germination and Seedling Performance of Cotton and Sesame under Projected Climate Conditions in Burkina Faso** 193
- SIMON ALIBU, DANIEL NEUHOFF, KALIMUTHU SENTHILKUMAR, MATHIAS BECKER, ULRICH KÖPKE:  
**Production Potential of Dry Season Maize in an Inland Valley in Central Uganda** 194
- ISABEL MUPFURUTSA, ANYWAY KATANHA, DOUGLAS MANYENGAVANA:  
**Inland Aquaculture and Resilience in Semi-Arid Spaces; The Case of Mukoma Village in Mt Darwin District, Zimbabwe** 195

ARASH MOHAMMADZADEH, JAVAD VAFABAKHSH, ABDOL-MAJID MAHDAVI DAMGHANI, REZA DEIHIMFARD, HOUMAN LIAGHATI, FATEME AGHAMIR: <b>Monitoring Sustainability of Saffron and Canola Production Systems in Maragheh, Northwestern Iran</b>	196
MARIE DUPRÉ, THIERRY MICHELS, PIERRE-YVES LE GAL: <b>Management of Agroecological Transitions Within Diversified Farms</b>	197
PAULINE DELLA ROSSA, CHARLES MOTTES, MARIANNE LE BAIL, PHILIPPE CATTAN, MAGALIE JANNOYER: <b>Sociotechnical System Analysis of Weeding, Key Step for Designing Agro-Ecological Systems at the Watershed Scale</b>	198

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## Conservation Agriculture: A Panacea for Food Insecurity among Smallholder Farmers in East Africa

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Low crop productivity among smallholder farmers in sub-Saharan Africa attributed to poor and declining soil health has led to severe food insecurity. Previous attempts to address this problem have been hampered by socioeconomic constraints of the smallholders who often are unable to afford the needed inputs for improving soil fertility. Conservation agriculture (CA) has been reported to be a sustainable approach for intensification of crop production in low input farming systems. Moreover, in rain fed agriculture, higher soil moisture content has been observed in CA systems compared to conventional systems. However the lack of empirical data to elucidate CA benefits on soil productivity have been scarce. This paper identifies CA as a low cost production strategy for improving soil productivity and enhancing crop yield. An experiment was conducted in western Kenya to test the effect of varying rates of crop residue retention on the recovery of applied nitrogen and soil water content on a maize crop. Soil was sampled at four different soil depths two weeks after application of calcium ammonium nitrate (CAN). It was observed that treatments receiving incremental amounts of crop residues as mulch had significant amounts of applied nitrogen within rooting depth compared to the control and thus increasing its availability for crop uptake. The crop had greater water use efficiency in plots receiving 8 t ha<sup>-1</sup> as crop residue. Cost benefit analysis showed that CA practices had between 20 to 30 % less labour cost compared to conventional practices. Conservation agriculture therefore portends a more cost effective strategy for improving soil productivity, better income due to reduced costs of labour and increased fertiliser and water use efficiency for the rural poor smallholder farmers in sub-Saharan Africa.

**Keywords:** Conservation agriculture, crop residue, maize, nitrogen use efficiency, water use efficiency

## Characterisation of Organic and Non-Organic Smallholder Farms: A Case of Highlands and Lowlands in Kenya

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The contribution of smallholder farmers is crucial for sustainable development in Kenya. These farmers are highly diverse and differ in many structural and functional aspects and any policy intervention targeting them requires a comprehension of this diversity. Among these smallholder farmers, the importance of organic farming is growing and its practice has received special attention from policy makers in recent years. In this study, a typology of smallholder farmers from a survey of 488 farm households in Kajiado and Murang'a counties in Kenya was developed using different multivariate analysis techniques. We found significant differences across five farm types determined through principal components and cluster analyses in terms of resource endowment, farming practices and other socioeconomic factors. Farm Types 2, 5 and 3 mainly practised organic agriculture, were market oriented and had high to medium levels of wealth as well as strong social networks unlike their counterparts in Types 1 and 4. Overall, the practice of organic agriculture was associated with higher agricultural income, legal ownership of land, older household heads, larger household sizes, stronger social networks, higher access to information, richer diets and higher levels of gender equity. On the contrary, poorer, younger and less well-connected farmers were less involved in organic agriculture. The typical farm types found in the two regions of study provide a baseline for further research in similar smallholder farming systems in Kenya and beyond. This study may help to design inclusive measures and incentives targeting also those farm types that currently do not apply organic farming principles necessary for successful policy interventions.

**Keywords:** Diversity, farm typology, gender, multivariate analysis, organic agriculture, policy

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## **The Potential of Alley Cropping as a Multi-Dimensional Strategy for Climate Change Adaptation in Africa**

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Climate change is more and more perceived as a global challenge for agricultural production, food security and human well-being. In particular drought prone regions and smallholder farmers face inevitable negative impacts on crop yields, soils and other ecosystem services by progressing global warming, changes in precipitation patterns and extreme weather events. Therefore, indicators and solutions need to be developed that combine several goals at once.

Within the Swiss project “Potential of Sustainable Land-Use Systems to Promote Adaptation to Climate Change”, several meta-analyses on the potential of agricultural techniques as climate change adaptation strategies in sub-Saharan Africa were conducted. Agroforestry is an often recommended potential sustainable agricultural practice. Its ways of implementation are diverse and range from long-term historic systems to newly established alley-cropping systems and its geographic distribution covers almost all parts of the world where trees grow.

This paper presents the results of more than 100 pair-wise comparison from alley-cropping experiments conducted in Africa between 1984 and 2012. It shows the effects of these agroforestry systems on the nutrient-use efficiency (NUE) compared to mono-cropping systems of cereal grain production, such as maize. The NUE is tested as a proxy-indicator to analyse the climate change adaptation potential of such systems. It allows insights into the water efficiency (particularly relevant for drought-prone regions), crop yields (relevant for the farmers) and the effects of management on soil resources (soil fertility). Additionally, other co-benefits of alley-cropping in Africa are reviewed, such as the influence on ecosystem services (e.g. carbon sequestration potential), on farmers (e.g. diversification of income sources) and other human well-being aspects (e.g. the provision of medicinal plant production). Further, the methodological challenges in comparing complex agroforestry systems with monocultural cropping systems are discussed.

Last, this paper gives insights and recommendations how alley-cropping systems can be utilised in Africa as a climate change adaptation strategy. It presents associated challenges of all dimensions (socio-cultural, economic and environmental) that currently prevent the progress of this agricultural technique. Therefore, the results address farmers, researchers and politicians alike.

**Keywords:** Agroforestry, meta-analysis, N use efficiency, pair-wise comparison

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## On-Farm Evaluation of Yields and Yield Gaps of Rainfed Lowland Rice Using Good Agriculture Practices

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Smallholder rice farmers in Tanzania often obtain yields of less than 2 t ha<sup>-1</sup>. The vast majority of them use local varieties and no mineral fertiliser at all. We investigated whether good agriculture practices (GAP) could help to improve yields and reduce the yield gaps in farmer fields.

Field trials with cv. SARO5 were carried out in three hydrological zones (Fringe, Middle and Center) of the Kilombero floodplain in Ifakara, Tanzania in 2015 and 2016 using different GAP. Eight treatments with four replications were compared in a one RCB design including; i) farmers practice (no bunding and no fertiliser, one hand-weeding), ii) unfertilised control (bunding, leveling and weeding), iii) ii + 60 kg N ha<sup>-1</sup>, iv) ii + 120:60:60 kg NPK ha<sup>-1</sup>, v) ii + pre-rice green manure (*Lablab purpureus*), vi) ii + farmyard manure (60 kg N ha<sup>-1</sup>), vii) ii + post rice forage legume (*Stylosanthes guianensis*) and viii) vi + residues of post-rice *Vigna unguiculata*. Crop growth parameters and yield were assessed and data submitted to ANOVA.

Grain yields ranged between 2.1 and 10.7 t ha<sup>-1</sup>. Significantly higher yields were recorded in 2015 compared with 2016 and in the fringe versus the middle zone. Plant height, tiller number and biomass at different rice growth stages were significantly increased by GAP, irrespective of the hydrological position. Simple bunding and levelling of the plots increased yields by 35 % compared to traditional farmers practice. Green manure application provided an additional 8 % yield benefit and the combination of FYM and cowpea added another 35 % of yield gain, however only in 2016. Application of urea and of NPK fertilisers resulted in the highest yield increase (40 and 53 %) compared with the unfertilised control. Thus, the site-specific adoption of different GAP components can contribute to reduce the rice yield gaps in the Kilombero floodplain.

**Keywords:** Farmyard manure, field bunding, floodplain, green manure, mineral fertiliser, SARO 5, Tanzania

## **Contribution of Local Agroforestry Systems to Food and Nutrition Security of Small Farming Households in Yayu, Southwestern Ethiopia**

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Ethiopia is the home of more than 30 million undernourished people, the fourth largest amount per country in the world. Among the existing approaches to cope with food and nutritional insecurity, agroforestry appears to be one of the most cost-effective alternatives. Hence, this study characterised the predominant agroforestry practices of small farming households in the Yayu Biosphere Reserve, Ethiopia by emphasising their contribution to local food and nutritional security. The study was conducted in 2014–15, during which 300 households were selected using a multi-stage random sampling design which considered the proximity of the sampled villages to the forest and market/road. Data was collected by applying a semi-structured survey and through field observation. Descriptive statistics, ANOVA and Pearson correlation analyses were used to estimate the extent and variation of local agroforestry practices. Results show that three predominant agroforestry practices, namely home-garden (HG), multistorey-coffee-system (MCS) and multipurpose-trees-on-farmlands (MTF), are practised by 99.7%, 93%, and 82% of households, respectively. MTF is mainly used for food production, MCS for income generation and HG for both. From all three practices, 127 useful plant species were identified, of which 42.5%, 25.9%, and 31.5% were trees, shrubs, and herbs respectively. Proximity to market is significantly associated with the number of useful species in HG ( $r=-0.289$ ;  $p < 0.01$ ) and MCS ( $r=-0.333$ ;  $p < 0.01$ ). Out of the ten major plant utility groups, seven were present in all three practices, i.e. food, fodder, fuel, shade, timber, NTFP and medicinal. 80 edible species were identified in all three practices, of which 55 were primarily cultivated for household food supply. Regarding the food groups, only 'spices/condiments/beverages' was found in MCS, and 'cereals' and 'legumes' in MTF, while in HG all of these as well as 'roots/tubers', 'vegetables', 'dark-vegetables', 'sweets' and 'fruits'. In HG and MTF the species count and richness of food groups per household was significant ( $p < 0.01$ ). Income provision comes from four major sources, MCS (60%), HG (18%), MTF (13%) and off-farm activities (11%). Based on the observed diversity, purpose-specialisation, and synchrony of the three agroforestry practices, we conclude that they contribute considerably but in different ways to all pillars of food and nutritional security of households of Yayu.

**Keywords:** Homegarden, multipurpose trees, multistorey coffee system

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## Global Warming Potential of Diversified Tropical Rice Rotation Systems after Straw Return and Legume Intercropping

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Paddy rice cultivation is increasingly challenged by irrigation water scarcity, which is forcing farmers to change traditional rice cultivation from flooded double-rice systems to the introduction of well-aerated upland crops during dry season. Emissions of methane (CH<sub>4</sub>) are expected to decrease, while there is a risk of increasing emissions of nitrous oxide (N<sub>2</sub>O) and decreasing soil organic carbon (SOC) stocks through volatilisation in the form of carbon dioxide (CO<sub>2</sub>). We present a unique dataset of long-term continuous greenhouse gas emission measurements (CH<sub>4</sub> and N<sub>2</sub>O) in the Philippines to assess global warming potentials (GWP) of diversified rice crop rotations including different crop management practices such as straw residue application and mungbean intercropping.

Since 2012, more than four years of CH<sub>4</sub> and N<sub>2</sub>O emissions in double-rice cropping (R-R) and paddy rice rotations diversified with either maize (R-M) or aerobic rice (R-A) during dry season have been collected. Introduction of upland crops reduced irrigation water use and CH<sub>4</sub> emissions by 66–81 % and 95–99 %, respectively. Although annual N<sub>2</sub>O emissions increased twice- to threefold in the diversified systems, the strong reduction of CH<sub>4</sub> led to a significantly lower annual GWP (CH<sub>4</sub><sup>+</sup> N<sub>2</sub>O) as compared to the traditional R-R system.

Diversified crop management practices were first implemented during land-preparation for dry season 2015 where i) 6 t ha<sup>-1</sup> rice straw was returned to the field and ii) mungbean was grown as a cover-crop between dry and wet season in addition to rice straw application. The input of organic material (straw and mungbean) led to higher substrate availability for methanogens during the following season. Therefore, GWP was 9–38 % higher following straw incorporation than the control treatment. This increase was mainly driven by increases in CH<sub>4</sub> emissions. Due to both stimulating CH<sub>4</sub> and N<sub>2</sub>O emissions mungbean intercropping further increased GWPs, whereby the increase was highest in the R-R rotation (89 %) and lowest in the R-M rotation (56 %).

Nevertheless, regarding a future expansion of lowland-upland rotations due to water scarcity in SE-Asia it can be expected that input of crop residues can counteract the SOC loss that is likely associated with the shift to more aerated soil conditions under upland crops.

**Keywords:** GWP, maize, methane, mungbean, nitrous oxide, paddy rice, residue management, SOC

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## Increasing Crop Productivity in Rainfed Rice Systems of Central Uganda

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Smallholder farmers in Uganda generally obtain low rice yields. With increasing rice consumption and high (but volatile) local production is rapidly expanding. Aiming to improve crop management and maintain soil fertility, this study explores management strategies for rainfed rice production in valley swamps of Uganda. The research is embedded in a GlobE Project, which assesses the potential of wetlands to contribute to food security while promoting a sustainable use.

Management practices compare single-season rice cropping applying common farmers' practice, with different improved management strategies (bunding, levelling and weeding), nutrient management (mineral vs. organic) and intensified rice double cropping. A randomised complete block design was repeated at three toposequence positions of an inland valley swamp for three consecutive seasons at Namulonge, Central Uganda. We assessed crop biomass accumulation, grain yield and nutrient uptake, as well as changes in soil attributes.

Simple soil and crop management practices such as field bunding and levelling, and increased frequency of weed control significantly increased grain yield from 1.8 to 3.1 t ha<sup>-1</sup> in 2015. Maximum attainable yields of 6.3 to 7.2 t ha<sup>-1</sup> were reached with full mineral NPK (120:60:60) application and the provision of supplementary irrigation. The application of chicken and green manure appear to be promising alternatives to mineral fertilisers, increasing average yields to 5.0 t/ha. The benefits of the suggested management options differed by hydrological position. In 2015, rice yielded less in the flood-prone centre positions. Response to applied mineral fertiliser was highest in the middle positions. Grain yields and response to organic amendments tended to be highest in fringe positions. In consequence, there is a need for site-specific management strategies, depending on the hydrological situation within the wetland.

**Keywords:** Cropping intensity, farmyard manure, green manure, inland valley, NERICA 4

## Effects of Diversified Rice-Based System on Nutrient Balances and Yield Gaps in the Philippines

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The green revolution with the development of high-yielding rice varieties in combination with the use of synthetic fertiliser and pesticides, and the provision of irrigation water, allowed for cultivating two crops of rice per year. However, the high water demand for the dry season rice can no longer be met in water-scarce environments, forcing farmers to replace dry season rice with upland crops. The short turn-over times in rice double cropping require the rice straw of the preceding crop to be removed or burnt. Replacing dry season rice with an upland crop will result in seasonal variations of the soil aeration status that may affect soil C and N contents. On the other hand, the return of rice straw by mulching or incorporation before maize can add K and Si. The inclusion of a pre-rice green manure after maize may contribute to conserve native soil N. We hypothesise that the emerging flooded – aerobic cropping systems enhance nutrient cycling and increase yield and nitrogen use efficiency of rice. Such effects may provide new opportunities for sustainably intensifying production while saving water and reducing the existing gaps between potential and actual yields.

In the Philippines, these gaps were quantified at 4.2–7.8 t ha<sup>-1</sup> in rice double cropping systems. With the aim of reducing yield gaps in diversified cropping systems, we compared rice double cropping with rice-maize rotations over two years in three main rice-growing regions of the Philippines, namely Laguna, Tarlac and Pangasinan. We compared the effects of permanent flooding and alternating seasonal drying and wetting of the soil, and assessed the effects of straw return during the wet-to-dry season transition period after the harvest of wet season rice (K and Si cycling) and of including a nitrogen-fixing green manure (*Vigna radiata*) during the dry-to-wet season transition period after maize harvest and the transplanting of rice (N cycling).

Across systems, sites and years, we established partial nutrient balances and N use efficiencies, seasonal soil N dynamics and determined yields, yield gaps in 24 double rice and 24 diversified rice-maize fields. Preliminary findings of the 2016 rotation experiments will be presented and discussed.

**Keywords:** Nutrient cycling, *Oryza sativa*, straw management, *Vigna radiata*, *Zea mays*

## Assessing Yield Responses in Cassava - Maize Intercropping Across Diverse Environments in Southern Nigeria

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Intercropping of cassava with maize is a common practice in Nigeria and many countries in the humid and sub-humid agro-ecological zones in sub-Saharan Africa. Maize is commonly harvested and sold fresh, thus, serving as a crucial early source of cash income for the farmer. In the framework of the African Cassava Agronomy Initiative (ACAI), a decision support tool (DST) is being developed to assist development partners in southern Nigeria to improve the productivity of the cassava-maize intercropping system by providing information on improved planting density, variety choice and fertiliser application for farmers. Here, we will present data of the first year from 100 multi-locational on-farm trials across the humid forest and derived savannah agro-ecological zones in Anambra, Cross River, Benue, Ogun and Oyo states. Two researcher-managed trials were established in Oyo and Anambra states. In the on-farm trials we tested the robustness of treatment response to increased planting density of maize and cassava of 40,000 and 12,500 plants ha<sup>-1</sup>, respectively, and the response to two fertiliser regimes (both at increased planting density), adjusted to either the requirements of maize or those of cassava. The control (no fertiliser, 10,000 cassava and 20,000 maize plants ha<sup>-1</sup> mimics farmers' practice). In the researcher-managed trials, we added ridging versus flat land preparation, a comparison with a branching cassava variety and the sole crops of maize and cassava. Preliminary analysis of maize harvest data showed that median cob numbers per plot increased with plant density and fertiliser application. Cob yields increased when fertiliser was applied. For both crops, maize and cassava, we will present cumulative distributions for the stepwise increases in intensity for the on-farm trials, and ANOVA results for the researcher-managed trials, and how these results serve the development of a first version of the DST.

**Keywords:** Cassava, decision support tool, density, fertiliser, inter-cropping

## Smart Designed, Mechanised Large-Scale Cocoa Plantations as a Forward-Looking Component of Sustainable Cocoa Production

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To meet the rising demand in the 1960s and 70s, smallholder farmers, especially in West Africa, started to increasingly grow cocoa. In order to generate higher incomes and to overcome price fluctuations, farmers intensified their farming strategies which led to an intermediate improvement of livelihood but also to a higher dependency on cocoa. Today, farmers get a share of about 6–10 % of the high-end chocolate product compared to 15–23 % in the beginning of the 60s. Thus they often miss the up-to-date knowledge, network and financial background to run highly intensified cocoa cultures in a sustainable way. Among others this led to extensive use of agrochemicals without increasing productivity in long-term. Land scarcity due to deforestation and soil degradation processes is becoming an important issue in many tropical countries. Besides, climate change is expected to seriously affect the present cocoa growing regions.

Smart designed large-scale projects would be able to increase and sustain productivity in long-term by combining modern planting material, soil conservation and adjusted management by optimising the existing processes and including present scientific findings. Thus, such projects could have the means to combine regional, national and global interests, protect nature reserves and support the development of rural communities by involving the rural population.

Large-scale plantations may include more than 100 shade trees of different species per hectare while providing a stable production of 1000 kg of dry cocoa per hectare per year, compared to the annual production of often only 350 kg per hectare on smallholder plantations. The approach is comparable to modern fruit orchards where the productivity per worker is increased by the use of machines that allows working more efficiently.

**Keywords:** Agro-industrialisation, agroforestry-systems, cocoa, large-scale, sustainable land-use

## Effects of Seed Sizes and Varieties on Growth, Yield, and Oil and Protein Contents of Groundnut (*Arachis hypogaea* L.)

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Two experiments were conducted at upland farm of Yezin Agricultural University in Nay Pyi Taw, Myanmar during rainy season 2010 and winter season 2010–2011. The field experiments were laid out in a split-plot design with three replications. The main plot factor was the four groundnut varieties, which were Sinpadaethar 7, Sinpadaethar 8, Sinpadaethar 9, and Magway 15. The sub plot factor was the three seed sizes, which were graded as small, medium, and large with the use of different sizes of sieves.

The effects of groundnut varieties on the yield and other related characters were found to be obvious and significant. The higher pod yield, number of pods per plant, shelling percentage, harvest index, and oil content were observed to be highest in Sinpadaethar 7, and this variety should be recommended to be applied for effective production in terms of pod yield in rainy and winter seasons. The highest protein content was observed in Sinpadaethar 9 and Magway 15 in rainy and winter season, respectively. The effects of size of planting seeds on plant characters were not as obvious as that of variety. The plants from large seeds indicated faster growth rate, especially in the initial growth stage as expressed in higher mean values of plant height, total dry matter, crop growth rate and harvest index in both season. At later growth stages, no significant differences were observed for the above parameters. Oil and protein contents were slightly affected by seed size. Yield components, harvest index and shelling percentage were not affected by seed size.

The interaction between varieties and seed sizes was not found in all observations. Therefore, choice of seed size or variety can be done independently for groundnut production. Based on the findings of this study on the effect of seed size on yield, it can be recommended that the smaller seeds can be used as the seed stock for groundnut growers whereas medium and large seeds can be used for their income.

**Keywords:** Groundnut, Myanmar, seed sizes, varieties, yield components

## In the Shadow of Large Infrastructure Development: Sustainability of Sawah Surjan Systems in Yogyakarta, Indonesia

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The South Coastal Regions of Yogyakarta Province in Indonesia inherited a unique farming system called *sawah surjan*. It is considered as a cultural heritage, demonstrating a form of local wisdom in managing land resources with poor drainage. The system shows two different but complementing land uses: first, the raised beds for various cash crops and second, the sunken beds for rice and fish. Geomorphologically the region comprises fluvio-marine lands, occupies the back swamp zone of the coastal zone of Kulonprogo Regency. The local knowledge of the rural dwellers of Kulonprogo Regency has succeeded in realising the farming system as an ecologically stable and able to provide a decent living for them. The farming systems as a cultural heritage have been under an increasing threat of conversion for urban settlements. Presently the area is undergoing a massive infrastructure development that increases the risk of land conversion of the *sawah surjan* into different land use designations. The construction of new arterial road along the coastal region of the province has further encouraged large scale investments by governments and private companies (iron ore mining, international airport, sea harbors, naval base) and smaller size of investments by the locals (governments, companies and community groups; especially those related to development of community-initiated tourism destinations). Many of the locals have also received substantial financial compensation for their lands, but there is an emerging question on their capability in sustaining their financial resources and to anticipate the emerging opportunities from the development of the new infrastructure. This study aims at assessing the prospects and sustainability of *sawah surjan* as a special farming system in facing the on-going large scale investments. The paper will focus on how and to what extent large-scale infrastructure development in the province has marginalised or provided new opportunities for the sustainability of the existing traditional farming systems.

**Keywords:** Indonesia, infrastructure development, large scale investment, *sawah surjan*, sustainability

## Evaluation of Agronomic Interventions Regarding Productivity and Profitability on Smallholder Farms with Wheat Production in Arsi, Ethiopia

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In Ethiopia average agricultural productivity can be considered being low. The production methods are basic, labour intensive, and with low capital and external inputs. To improve efficiency in terms of productivity and profitability different agronomic interventions are tested on 593 randomly sampled smallholder farms (SHF). The types of interventions comprise tractor ploughing, harrowing (tractor mounted), row seeding (tractor mounted), improved seeds/varieties, recommended dosage and timing of fertiliser, herbicide and fungicide application.

The aim is to enhance the understanding of wheat farming systems in Arsi and to evaluate the agronomic interventions regarding productivity and profitability.

The research approach is mono-factorial. On each sampled wheat producing farm one farm section is “treated” with one intervention whereas the other part is still managed as before in order to allow comparison (“with” and “without”). The harvest data was collected on 227 SHF in a pre-harvest field assessment by collection of wheat samples counting number of heads per m<sup>2</sup>, number of seeds per head and thousand kernel weights. In order to cross-check, farmers were additionally surveyed in a post-harvest assessment. To analyse data Microsoft Excel 2010 and the statistical program R version 3.2.2 were employed, the latter to test for significance by applying t-tests.

The results of the farming systems analysis show a mean land size of 1.7 ha with a mean wheat yield of 2.64 t ha<sup>-1</sup> (2014).

The results for the pre-harvest assessment display a mean wheat yield of 4.3 t ha<sup>-1</sup> for intervention and 3.4 t ha<sup>-1</sup> for control plots, the post-harvest assessment 4.7 t ha<sup>-1</sup> for intervention and 3.9 t ha<sup>-1</sup> for control plots (2016). For all interventions highly significant ( $p < 0.001$ ) differences in regards to productivity were found when compared to the control plots. The average wheat yields of intervention plots indicated following increases: tractor ploughing 21% higher wheat yields, harrowing 9%, improved seeds 32%, row seeding 28%, fertiliser application 21.5%, herbicide application 22.5%, and fungicide application 30% higher wheat yields, respectively. Therefore, the gross margin increased by about: 24% through the application of tractor ploughing, 0.4% for harrowing, 36% for the use of improved seed, 30% for row seeding, 25% for fertiliser-, 27% for herbicide-, and 38% for fungicide application.

**Keywords:** Ethiopia, interventions, productivity, profitability, smallholder, wheat

## Assessing the Needs for Different Climate Change Adaptation Strategies in Ghana's Cacao Sector

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Assessing the needs for climate adaptation in West African cacao production over the next decades requires spatially detailed analysis of climate impacts. We use the impact assessment of Bunn *et al.* (unpublished) on how climate change will affect the suitability of cacao in Ghana over the next decades. They outline specific adaptation strategies for different climate impact zones. Here we estimate the current share of households dependent on cacao as well as the share of production that are located in these zones.

Using a Random Forest machine learning approach to model occurrences of cacao depending on several relevant bio-climatic and soil-related variables, Bunn *et al.* find four different suitability zones for cacao in Ghana. Moreover, they employ down-scaled RCP 6.0 climate projections to estimate the change in suitability up to the 2050s. Depending on the changes in suitability, they propose five different types of adaptation strategies: Opportunity refers to zones that are currently unsuitable for cacao but will probably become suitable in the future. Transformation is required in suitable areas which are projected to become unsuitable. In areas transforming from one suitability type to another, cacao production will be possible but under different conditions and systemic adaptation is recommended. If the suitability type remains the same, incremental adaptation is proposed. Finally, in regions where there is low model agreement on the future climatic suitability of cacao, a strategy of systemic resilience is suggested.

We assign current data from the 2010 Population and Housing Census of the Ghana Statistical Service and cacao production statistics from the Ghana Cacao Board to the climate impact zones specified by Bunn *et al.* We find that about 40 % of the households and 35 % of the current production in Ghana are located in areas that require systemic adaptation. Only about 10 % of the households and 4 % of the production are located in areas which will become unsuitable for cacao (transformation). Hence, although only a minor share of activities is located in regions that are projected to become fully unsuitable, there is a considerable share of areas that still require different strategies of adaptation to actually maintain cacao production.

**Keywords:** Cacao, climate adaptation, Ghana

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## Effect of Agronomic Practices on Growth and Leaf Yield in *Gynandropsis gynandra* (L.) Briq.

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*Gynandropsis gynandra* is an African leafy vegetable with high nutritional and medicinal values. However, its production is constrained by poor germination and inadequate agricultural practices. This study assessed the effects of seedlings age at transplanting, planting spacing and cutting frequency on growth and yield in *Gynandropsis gynandra* in order to improve its production in urban and peri-urban agriculture. Seedlings were transplanted at two ages (two weeks and three weeks after sowing) and three spacing (15 cm × 15 cm; 20 cm × 20 cm and 30 cm × 20 cm). They were harvested following three cutting intervals (one week, two weeks and three weeks after the first harvest). Those factors were factorial combined and evaluated in a randomised complete block with three replications. Growth parameters including plant height, stem diameter, number of leaves and branches, leaf length, leaf width and leaf area as well as yield parameters such as total fresh and edible biomass and dry matter content were measured. Analysis of variance and generalised linear model were used to analyse the data collected. The results revealed that seedlings age, plant density and cutting frequency have significant effects on growth and biomass yield without interaction. Seedlings at two weeks' age grew better during the 21 days after transplanting while three weeks old seedlings responded better after cutting. The planting spacing of 15 cm × 15 cm gave a higher biomass yield (29 t ha<sup>-1</sup>) while plants at two weeks after the first harvest regrew better with a higher biomass. No significant effect was noted on leaf area ( $p > 0.05$ ) at each harvest but it decreased through time in contrast to dry matter which increased. These results offer new insights into best agronomic practices for cultivation of the species.

**Keywords:** African leafy vegetables, cutting frequency, leaf yield, planting spacing, seedling age, spider plant

## Germination and Seedling Performance of Cotton and Sesame under Projected Climate Conditions in Burkina Faso

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Cotton (*Gossypium hirsutum*) and sesame (*Sesamum indicum*) are the major export commodities of Burkina Faso. More than 80 % of the population depend on rain-fed agriculture. The projected warming over Africa for the 21<sup>st</sup> century is higher than the global rate, but most likely to occur over West Africa 1–2 decades earlier between late 2030s to early 2040s. Using climate conditioning chambers we analysed germination rate, emergence time, survival time and seedling performance (root and shoot length, biomass) of 200 cotton and 200 sesame seeds under recent and projected climate conditions. Seeds were obtained at site (Bankandi, 11°08'56.566" N, 003°03'36.446" W). High resolution (12 km) regional climate simulations were carried out at Karlsruhe Institute of Technology (KIT/IMK-IFU) as part of the West African Science Service Center on Climate Change and Adapted Land Use (WASCAL) Project. The projected climate conditions were modelled for the year 2040 in Bankandi for the months of June and July (higher temperature and lower relative air humidity above surface (rH in %) during the sowing and early recruitment phase). Recent climate data were collected at site hourly from 2013–2015. Climate chambers were set with a day/night rhythm (12h light/12h dark). Temperatures and rH were set 29,3°C (recent) / 30,7°C (projected) and 71,4% / 62,5 % at day time. Night time was set as 26,8°C (recent)/ 29,5°C (projected) and 81,3%/ 72,4 %, respectively.

Germination rate and emergence time did not differ significantly between recent and projected climate conditions in both crop species. However, survival rate and biomass of sesame seedlings were significantly higher under recent conditions. Under projected conditions with higher temperatures and lower rH, sesame roots were significantly more branched than under recent cooler and wetter conditions. No significant differences of germination and seedling performance could be detected in cotton.

Sesame seems to suffer from heat stress and might be more sensitive to climate change than cotton. Varieties of both crop species should be heat and drought resistant to secure future yields and income for the local smallholders.

**Keywords:** Biomass, Burkina Faso, climate chambers, climate change, cotton, germination, sesame, survival, West Africa

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## Production Potential of Dry Season Maize in an Inland Valley in Central Uganda

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Maize is the main food staple in East Africa contributing over 50 % of total calories consumed. A shortage of maize causes food insecurity. Inland-valley wetlands with enhanced soil moisture than surrounding top-lands provide opportunities for growing off-season maize. We assessed the potential of an inland-valley in central Uganda for producing dry-season maize. Two consecutive field experiments were conducted in three hydrological zones (fringe, middle and centre) under different nutrient management options. Average grain yield in the inland valley ( $3.8 \text{ Mg ha}^{-1}$ ) exceeded the national production average of upland maize by 60 %. Grain yield was high at  $5.0 \text{ Mg ha}^{-1}$  and more stable in the centre of the inland valley and clearly lower at  $3.2 \text{ Mg ha}^{-1}$  in both the middle and fringe. There was a seasonal influence on the production capacity of different hydrological zones. During the short dry-season with more rainfall, the centre produced about 25 % higher grain yield ( $6.3 \text{ Mg ha}^{-1}$ ) than the fringe and middle. In the long dry-season with less precipitation, grain yield in the centre ( $3.6 \text{ Mg ha}^{-1}$ ) was lower, but still about 50 % higher than yield in other hydrological zones. Grain yields were highest with  $120 \text{ kg ha}^{-1}$  inorganic N fertiliser, but similar to yields with  $120 \text{ kg ha}^{-1}$  organic N supplied by chicken manure ( $60 \text{ kg N ha}^{-1}$ ) and green-manure ( $60 \text{ kg N ha}^{-1}$ ). Irrespective of the source,  $60 \text{ kg N ha}^{-1}$  did not produce a noticeable yield advantage over the unfertilised control. According to our results, maize cultivation can be restricted to the centre during the dry-season with less expected rain, and expanded to the fringe and middle positions in the dry-season when more rain is expected. A low-cost fertiliser combination of green manure and chicken manure can sustain maize productivity in the inland valley.

**Keywords:** Climate change, East Africa, food security, wetlands

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## **Inland Aquaculture and Resilience in Semi-Arid Spaces. The Case of Mukoma Village in Mt Darwin District, Zimbabwe**

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Rural poor who reside in semi-arid regions of sub-Saharan Africa (SSA) are documented to be amongst the most affected by climate change, especially if they depend on rain-fed agriculture only. However, many of these rural farmers have been able, based on their available eco-resources, to diversify farming activities. Though given less attention, important inland fisheries are practiced in different semi-arid regions of the world. Seasonal small scale aquaculture is practiced by some villagers in the semi-arid region of northern Zimbabwe and contributes to their nutrition and food security. This study looked at the complex geographies of small scale aquaculture and investigated how aquaculture based livelihoods adjusted to climatic changes. Secondary sources, field observations, semi-structured interviews (n= 62) and focus group discussions (n=10) were used to solicit data in Mukoma village (North Zimbabwe) between January 2017 and May 2017. Analysis of collected data was done qualitatively through establishment of categories, themes and relations. The study revealed that small scale fisheries are important to assure livelihood of the rural poor, to compensate the often low yields of their rain fed agriculture. Evidence from the study suggest that small scale fishers in this semi arid space respond to climate change by enhancing teamwork and stewardship actions which suggest high adaptive capacity. Results suggest a sound potential for local stewardship, institutions and human activity in semi-arid small-scale fishing communes in the face of climate change. However, the overall adaptive capacity of the Mukoma community to the climate change effects is rather low and the fishers in particular are very susceptible to the climate change effects. The study argues that in order to sustain this small scale fishery activity, which has an important economic, nutritional and social function, a planned pro-poor adaptation strategy at different scales (from local to regional) has to be developed.

**Keywords:** Adaptation, climate change, fisheries, livelihoods, vulnerability

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## Monitoring Sustainability of Saffron and Canola Production Systems in Maragheh, Northwestern Iran

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Diminishing environmental quality and rendering natural resources are increasingly pushing agroecosystems toward more sustainable and environmental-oriented approaches for crop production. Saffron is a valuable and economically strategic crop in Iran with an 80 % of world total production in the country. Canola is one of the most important oilseed crops in Iran regarding its good yield potential in the country and great dependence of Iran to import oilseeds. In the present study, sustainability of saffron and canola production systems was evaluated using quantitative indices including energy efficiency, global warming potential (GWP), economic indicators, pesticide risk (field environmental impact quotient - FEIQ), fertiliser, labour and water use efficiency. Data were collected by face to face interviews with all growers of saffron and canola (25 for saffron and 30 for canola) in the Maragheh Plain, northwestern Iran and 15 experts of the Ministry of Agri-Jihad in the study area. Results showed that canola production was more energy-intensive than saffron production. The share of the non-renewable energy of total energy used in the canola production system (83.7 %) was higher than the renewable energy used (16.3 %), but the share of renewable energy in the saffron production system (54.6 %) was greater than the non-renewable form (45.4 %). The GWP of the GHG emissions for canola was estimated being higher than for saffron (1671.2 vs. 646.2 kg CO<sub>2</sub>eq ha<sup>-1</sup>). The eco-efficiency based on GWP was 1.54 and 8.66 USD kg<sup>-1</sup> CO<sub>2</sub> eq for canola and saffron, respectively. The FEIQ value was 63.1 ha<sup>-1</sup> for saffron and 68.9 ha<sup>-1</sup> for canola. Results revealed that water and nutrient economic productivities were higher in saffron than canola. In terms of economic labour productivity, however, the canola production system was more efficient. It can be concluded that saffron production system was more sustainable than canola-based agroecosystems.

**Keywords:** Energy efficiency, global warming, nutrient use efficiency, pesticide

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## Management of Agroecological Transitions within Diversified Farms

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Agroecological systems should integrate increased cultivated and non-cultivated biodiversity in order to achieve their objectives. However, studies on agroecological transitions have been mainly conducted on highly specialised farms. This study aims to understand how farmers manage agroecological transitions in farms combining different crop and livestock productions. A generic framework was applied to compare crop/livestock production managements within thirty diversified farms cultivating citrus in the Réunion Island. The sample covered multiple forms of diversification: farmers growing a diversity of fruit trees, farmers combining fruit trees with semi-perennial fruit species and market-gardening, and farmers combining crop and livestock productions. Trajectories of practices were also investigated to rebuild the sequence of changes' introduction in each farm. The study showed firstly that constraints and opportunities to agroecological transitions were specific to each production. These specificities included both agronomic features, such as sensitivity to pests, perennial or annual nature, open-air or confined farming and surface areas, and economic features, such as market demand, product traceability, added-value and alternative input availability. Then, interactions between productions appeared to facilitate a progressive transition for farmers. Benefic exchanges of information, matter and labour were identified. Some farmers tested alternative practices at first on one production, such as mechanical weeding, and then extended the successful practices to other productions. They could innovate on their main production for which they allocated more time, for instance by introducing cover crops. Or they could innovate on secondary productions for which they could take more risks, by reducing significantly synthetic inputs use. Biological processes were enhanced by matter exchanges between productions, especially on farms combining crops and livestock. Labour organisation was improved by some alternative practices with different labour period or frequency, such as chemical traps or mulching. The specific features of each production may complicate the design, the support and the management of agroecological diversified farming systems, but diversification enhances agroecological transition because of production synergism and low-risk progressive pathways of change.

**Keywords:** Agroecology, diversification, dynamics of change, farm level

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## Sociotechnical System Analysis of Weeding, Key Step for Designing Agro-Ecological Systems at the Watershed Scale

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In Martinique (French West Indies) there is high pesticide pressure because of monoculture with high demand of farm inputs, linked to tropical conditions suitable to the growth of pathogens and weeds. This pressure cause high river pollution, in particular herbicides pollution which are the most used pesticides on this island. Thus, it is urgent to decrease the uses of herbicides at the watershed scale. Our work proposes a participatory methodology to design innovative agricultural systems decreasing herbicide pressure on the river. The watershed scale is a coherent level for actions reducing river pollution because of the integration of continuous hydrologic flows. However, watersheds, such as our study site, usually hold a high diversity of farms and cropping systems that are integrated into social, economic and environmental contexts. This is the reason why our question is how making a participatory process suited for designing innovative agricultural systems onto a heterogeneous territory, for a common purpose of reducing herbicides uses? We conducted an in depth analysis of the sociotechnical system of agriculture in Martinique, to highlight brakes and levers of innovations at the institutional level, and the different innovation strategies of actors. Locks of the dominant regime explained why we are currently in a weak agroecological modernisation process of agriculture, focused on the maximal efficiency of farms inputs and the reduction of negative impacts, instead of redesigning agricultural systems (diversification, mixed cropping, agroforestry ...). The analysis of the sociotechnical system allowed us to understand the mechanisms at different levels (markets institutions and regulations, agrofood chains, local networks, farmers knowledge and information services...) that lock the system against radical innovation. We also showed the mechanisms of how innovation niches, from plot to regional institutions, can influence the dominant regime. This first step of our work allowed us to identify the main brakes to be reduced, the sources of local solutions for reducing herbicides and to choose pertinent actors for our participatory process. These results will be used to design together agricultural systems that are adapted to the socioeconomic context of our watershed.

**Keywords:** French West Indies, herbicides, innovation, participatory design, sociotechnical system, territory

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# Crop genetic resources and abiotic stress

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## Invited Paper

MATTHIAS WISSUWA:

**Unlocking Genetic Variation Stored in Gene Banks for the Benefit of Resource-Poor Farmers** 202

## Oral Presentations

ARISOA RAJAONA, TOVOHERY RAKOTOSON, HANNAH WRIGHT, JEMIMA AMIELLE RAMAROLAHY, KALIMUTHU SENTHILKUMAR, KAZUKI SAITO, ELKE VANDAMME:  
**Responses of Grain Yield and P Uptake to Water Management and Phosphorus in Lowland Irrigated Rice (*Oryza sativa* L.)** 203

LARA ERGEZINGER, TOAVINTSOA RAJONANDRAINAINA, LIN-BO WU, TOVOHERY RAKOTOSON, MICHAEL FREI:  
**Management and Genotype Effects on Resistance to Iron Toxicity in Lowland Rice in Madagascar** 204

ANNA PUCHER, CHARLES TOM HASH, OUSMANE SY, IGNATIUS IJANTIKU ANGARAWAI, JADA GONDAH, ROGER ZANGRE, MOUSSA D. SANOGO, MAHAMA. O. OUEDRAOGO, BETTINA I.G. HAUSSMANN:  
**Pearl Millet Breeding in West Africa – Steps Towards Higher Productivity and Nutritional Value** 205

ALEJANDRO PIETERS, SABINE STÜRZ, FOLKARD ASCH:  
**Impact of Root Temperature Regime on Growth, Photosynthesis and Carbon Allocation in Rice Plants** 207

## Posters

ARISOA RAJAONA, ANDO LALAINA RAZAFINDRAZAKA, BAYUH BELAY ABERA, BOSHUWENDA ANDRE CHUMA, KALIMUTHU SENTHILKUMAR, MARC COTTER, FOLKARD ASCH:  
**Multi-Country Analysis of Genotype × Environment Interactions of Lowland Rice to Improve RiceAdvice Prediction** 208

ANDO LALAINA RAZAFINDRAZAKA, MARC COTTER, ARISOA RAJAONA, FOLKARD ASCH:  
**Spikelet Sterility of Lowland Rice Related to Temperature at Booting Stage in Different Thermal Environment in Madagascar** 209



- BAYUH BELAY ABERA, MARC COTTER, KALIMUTHU SENTHILKUMAR, FOLKARD ASCH:  
**Variation in Phenological Development and Yield Performance of Rice Genotypes under Cold Stress in the Fogera Plain, Ethiopia** 210
- BOSHUWENDA ANDRE CHUMA, ELIE-RENE GASORE, KALIMUTHU SENTHILKUMAR, ARISOA RAJAONA, MARC COTTER, FOLKARD ASCH:  
**Adaptation of Fertiliser Application Strategies to Low Temperatures at High Altitudes Sites in Lowland Rice** 211
- TAHMINA ISLAM, M.K. REDDY:  
**Evaluation of Cd<sup>2+</sup> Stress Tolerance in Transgenic Rice by Overexpressing PgGPx Gene that Maintains Cellular Ion and Reactive Oxygen Species Homeostasis** 212
- SUMITRA PANTHA, SHAMBHU PRASAD KHATIWADA, KALYAN PANTHA, RESHAM BABU AMGAI:  
**Evaluation of Submergence Tolerance Characteristics on Nepalese Rice** 213
- YAYA HASANAH, LISA MAWARNI, TEUKU IRMANSYAH:  
**Production and Physiological Characters of Soybean under Drought Stress with Foliar Application of Exogenous Antioxidant** 214
- JULIA HOELLE, JESUS ZUMARAN, EVELYN FARAFAN, MERIDETH BONIERBALE, FOLKARD ASCH:  
**Drought Effects on the Synchrony of Aboveground and Belowground Phenology of Five Potato Clones** 215
- LEONILO GRAMAJE, JOANNE CAGUIAT, RENETH MILLAS, JAKE CARAMPATANA, QUIRINO DELA CRUZ:  
**Heterosis, Combining Ability and Genetic Relationship of Selected Parent Lines for Hybrid Rice Development** 216
- MOCTAR KANTE, H. FREDERICK W. RATTUNDE, WILLMAR L. LEISER, BALOUA NEBIÉ, BOCAR DIALLO, ABDOULAYE DIALLO, ABOCAR TOURÉ, IGNATIUS IJANTIKU ANGARAWAI, MARY YEYE, EVA WELTZIEN, BETTINA I.G. HAUSSMANN:  
**Sorghum Hybrids - A Contribution to Future Agricultural Productivity and Food Security in West Africa** 217
- VIRGINIA TAPAT, BELINDA TAD-AWAN:  
**Morpho-Genetic Characterisation, Diversity Analysis and Evaluation of Rice Landraces in Benguet** 218
- YASIR GAMAR, WILSON KIMANI, ELFADIL BASHIR:  
**Genetic Diversity and Structure of Wild Relatives of Sorghum Populations from Different Geographical Regions of Sudan** 219

FELIX SATTLER, ANNA PUCHER, OUSMANE SY, AHMAD ISAACA, CHARLES TOM HASH, BETTINA I.G. HAUSSMANN: <b>Identification of Combining Ability Patterns for Pearl Millet Hybrid Breeding in West Africa</b>	220
JOANNE CAGUIAT, LEONILO GRAMAJE, JAKE CARAMPATANA, FRODIE WAING, MARLON GARCILLANO: <b>Development of Hybrid Rice Variety (PR40638) with Bacte- rial Leaf Blight Resistance</b>	221

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## Unlocking Genetic Variation Stored in Gene Banks for the Benefit of Resource-Poor Farmers

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Over the past two decades, molecular approaches in crop science have moved from basic research to applications in plant breeding, plant pathology or food chemistry. In breeding these applications have typically developed out of QTL mapping approaches that fine-mapped loci or cloned candidate genes controlling the trait of interest, which allowed for the developed of molecular markers for use in marker assisted selection (MAS). To date the improvement of flooding tolerance of popular rice varieties through MAS for the *sub1* gene is one of the most successful examples of molecular approaches being used for development.

Rapid advances in genome sequencing technologies that have driven down costs to a level where representative sub-sets of crops stored in gene bank collections can now be sequenced promises to provide a new boost for molecular breeding efforts. In rice 3000 gene bank accessions have been sequenced and the data made publicly available through the SNP-Seek website hosted by the International Rice Research Institute (IRRI). Seeds of these sequenced rice accessions are also publicly available and are being phenotyped under a number of environments and stresses. Own work is currently evaluating genotypic variation for nutrient efficiency and grain yield under low-input conditions in Madagascar, as practised by the predominantly resource-poor farmers there. Through genome-wide association studies (GWAS) and allele mining within SNP-Seek, rare alleles ‘hidden’ in gene banks are now being identified as enhancing nutrient efficiency. Carriers of such rare but useful alleles are often traditional varieties developed by farmer-breeders under low-input conditions. After further confirmation of allele effects in subsequent candidate gene studies, the objective will be to introgress such alleles into modern rice varieties through MAS, using traditional varieties as donors. Thus, advances in molecular approaches have provided new impetus for the utilisation of genetic resources present in gene banks.

**Keywords:** Gene banks, genome sequencing

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## Responses of Grain Yield and P Uptake to Water Management and Phosphorus in Lowland Irrigated Rice (*Oryza sativa* L.)

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Phosphorus (P) deficiency constitutes a major growth and yield-limiting factor in irrigated and rainfed rice systems in Madagascar. Many soils in Madagascar are highly weathered with a high Fe oxyhydroxide content leading to P sorption and low P availability, and farmers often do not apply mineral P fertilisers leading to a continuous decline in soil P stocks. Appropriate agronomic practices should be designed to increase P availability and improve P fertiliser use efficiency to encourage the application of P inputs. P availability and P uptake by the rice crop may be affected by water management. It is known that relatively high soil water content under frequent irrigation increases soil P mobility and availability through reductive dissolution of P bearing Fe-oxides. On one hand, cycles of alternate wetting and drying (AWD) can increase P availability and acquisition under suboptimal P supply. On the other hand, as P availability often increases drastically upon flooding, we hypothesised that flooding during the grain filling stage may lead to luxury P loading in grains without increasing grain yield and hence low P utilisation efficiency. The objective of this study was to evaluate grain yield and P uptake of rice under different P rates and water management treatments. The experiment was undertaken in Behenjy (1361 m asl), Madagascar using X265 rice variety. A split-plot design was used with 3 irrigation treatments (continuous flooding, continuous flooding until flowering and then drained, and AWD) in main plots, 3 doses of P (0, 10 and 25 kg ha<sup>-1</sup>) in the sub plots, and 4 replications. Results on grain yield and P uptake of rice cultivated in lowland irrigated system, mainly under P stress will be discussed and presented.

**Keywords:** Alternate wetting and drying, Madagascar, P deficiency

## Management and Genotype Effects on Resistance to Iron Toxicity in Lowland Rice in Madagascar

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Iron toxicity is one of the major abiotic stresses affecting irrigated rice production in tropical areas where submerged paddy field soils are often characterised by excess soluble Fe. In Madagascar, the yield losses recorded due to Fe toxicity are about 10 to 50%. Although the use of tolerant varieties is generally the most prominent strategy to alleviate Fe toxicity, tolerance of the commonly disseminated and cultivated rice varieties remains non-elaborated. The aim of this study was to test the tolerance to Fe toxicity of a selection of local varieties and compare it to a selection of foreign varieties that had previously been ranked as tolerant or sensitive based on screening in hydroponics. Plants of 23 different genotypes were grown in a highly Fe toxic field site and in pots filled with Fe toxic soil (Fe total > 7%) placed in a greenhouse. Two different treatments involved (i) no fertiliser, and (ii) the recommended mineral and organic fertiliser dose, i.e. 10 t ha<sup>-1</sup> farmyard manure, 300 kg ha<sup>-1</sup> NPK, and 100 kg ha<sup>-1</sup> urea. The performance of each variety was assessed by determination of leaf bronzing score (LBS), biomass yield, Fe shoot concentrations in different growth stages and lipid peroxidation (malondialdehyde concentration, MDA). Additionally, tolerance mechanisms to Fe toxicity were determined by total root weight, amount of Fe plaque on the root surface and dehydroascorbate reductase activity (DHAR). Fertiliser application significantly reduced Fe concentrations up to 84% in shoots, coincident with a significantly higher yield. Despite a better crop performance in the fertilised treatment, the LBS was not lower compared to that in the non-fertilised treatment. Shoot MDA concentrations showed genotypic differences, however, not significantly correlated with the yield loss. Genotypic differences could be also significantly determined in the amount of root plaque formation and dehydroascorbate reductase activity, enabling hypothesis for tolerance mechanisms. Additionally, Malagasy varieties generally tended to produce higher yields compared to foreign varieties irrespective of Fe toxicity tolerance ranking. These results clearly indicate that adaptation to local conditions needs to be considered when breeding for tolerance to Fe toxicity. Fertiliser application can greatly improve the yield performance in Fe toxic fields.

**Keywords:** Fertilisation, iron toxicity, rice, variety screening

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## Pearl Millet Breeding in West Africa – Steps Towards Higher Productivity and Nutritional Value

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Pearl millet (*Pennisetum glaucum* (L.) R. Br.) is the most important staple crop for smallholder farmers in drylands of West Africa (WA) due to its high drought and heat tolerance. In future, these farmers will need more productive and more nutritious pearl millet varieties to combat hunger and hidden hunger in the region. To meet this challenge, we conducted three different, large multi-location trials, to evaluate the WA pearl millet genetic diversity for agro-morphological and grain quality traits, to determine the potential hybrid superiority over open-pollinated cultivars, and to develop complementary breeding strategies that lead to better performance, stability and grain micronutrient content.

Characterisation of a broad collection of 360 WA pearl millet landraces identified wide ranges for agro-morphological traits such as yield, flowering time, panicle length, etc., indicating tremendous diversity and the usefulness of germplasm exchange among national breeding programs. Grain iron and zinc contents showed significant genetic variation in a set of 72 WA landraces and moderate-to-high heritability ( $h^2=0.70$  for iron,  $h^2=0.53$  for zinc), which emphasises a high potential for biofortification breeding. In a multi-location trial evaluating 100 population hybrids and their 20 parental populations, population hybrids showed grain yield superiority of on average 16.7 % compared to their parental populations (ranging from -26 to 73 %), reflecting the great potential of hybrid breeding to increase pearl millet productivity. To achieve the required yield stability and robustness, genetically heterogeneous hybrid types should be preferred. Due to high genetic admixture among WA pearl millets, heterotic grouping, which is the basis of efficient hybrid breeding, is not feasible based on “naturally” distinct groups, thus combining ability studies are required, followed by a systematic development of heterotic groups. To facilitate the establishment of a male parent pool exhibiting fertility restoration, we identified molecular markers for male-fertility

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restoration in the A4 cytoplasmic male-sterility system in pearl millet. Such a system is required for economic hybrid seed production. The feasibility of hybrid seed production by WA farmer seed cooperatives has been demonstrated for sorghum in Mali. A similar approach should be followed for pearl millet, to facilitate smallholder farmers' access to the superior hybrid seed.

**Keywords:** Biofortification, hybrid breeding, pearl millet

## Impact of Root Temperature Regime on Growth, Photosynthesis and Carbon Allocation in Rice Plants

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Temperature is a key environmental factor affecting photosynthesis and crop growth, but most studies have focused on air temperature. Rice is mostly grown in flooded conditions in which the meristems are immersed in ponded water, so differences in night/day water temperatures are expected to have a large impact on growth. Rice plants, cv IR64 were cultivated in a greenhouse in an hydroponic circulating system in which the root and meristem growth temperatures were inverted in order to distinguish the effect of night-time and day-time temperature on growth and carbon balance. Air temperatures were kept constant at  $25^{\circ}\text{C} \pm 3 / 20^{\circ}\text{C} \pm 2$  day / night, respectively. After 28 days under the inverted day/night root-meristem temperature regime, plants were measured and sampled for total and organ dry weight, photosynthesis rate in the three uppermost leaves on the main stem and carbohydrate and soluble proteins distribution. Plants subjected to low day-/high night-time temperature ( $18^{\circ}\text{C}/28^{\circ}\text{C}$ ) showed a larger total, leaf, root and stem dry weight than plants subjected to high-day/low-night ( $28^{\circ}\text{C}/18^{\circ}\text{C}$ ) root-meristem temperature. However, leaf and stem biomass represented 30 % and 40 % of total plant dry weight, respectively in both treatments. Leaf area and photosynthetic rates were higher in the low-day/high-night temperature treatment but at the end of the light period, leaf carbohydrate concentration was larger in the high-day/low-night temperature treatment. The opposite was observed at the end of the dark period, which resulted in a higher fraction of accumulated carbon being mobilised during the dark period in the low-day/high-night temperature treatment. Leaf soluble protein concentration was higher in the high-day/low-night temperature treatment, particularly in leaf 1 (youngest) and leaf 3 (oldest), which led to a C/N ratio between 2.18 and 2.86 mmol  $\text{CH}_2\text{O}$  g protein<sup>-1</sup> in all leaf ages and both treatments. Our data indicate that inverting the root/meristem temperature regime (low day/high night) stimulates growth and leaf area development through the production of more tillers without major changes in biomass allocation. This could be partly explained by the faster rates of photosynthesis and the larger fraction of accumulated  $\text{CH}_2\text{O}$  which was remobilised during the night period.

**Keywords:** Carbohydrate mobilisation, carbon balance, rice, root temperature regime

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## Multi-Country Analysis of Genotype $\times$ Environment Interactions of Lowland Rice to Improve RiceAdvice Prediction

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Lowland rice accounts for 75 % of the world's rice production. It contributes to food security and poverty alleviation in Africa. However, the gap between potential and actual yield in Africa is still substantially wide. AfricaRice and its partners have developed a free android-based decision-support tool, named 'RiceAdvice' to improve farmers' decision making and to enhance productivity (yield and income) in lowland rice systems in West East Africa at both low and high altitudes. RiceAdvice provides users with personalized advice on rice management practices: cropping calendars, best agricultural practices, and soil fertility management. So far, it has helped to gain 0.6 to 1.8 t ha<sup>-1</sup> of yield, equivalent to an income gain of \$100 to \$200 per ha. RiceAdvice is ready for use in 5 countries and under testing in 9 countries in Africa. This tool is based on detailed physiological field experiments. Knowledge of genotype-specific parameters for rice varieties and daily weather data obtained from 'Rice Garden Trials', can be used in a validated crop simulation model. The later provides estimation of growth duration and timing of specific development stages for each variety, as well as expected yield losses due to cold or heat stress. In addition, matching timing of application, amount, and nature of fertiliser with crop development stages will be acquired from 'Nutrient Omission Trials'. We report here experiments undertaken in Madagascar, Ethiopia and Rwanda at different altitudes, using 4 contrasting rice genotypes (Yunkeng, IR64, Chhomrong, X-Jigna). In Madagascar, 12 planting dates monthly staggered in 2 locations were used in a non-replicated split-plot design. In Ethiopia, the varieties were planted under two different crop establishments (transplanting and direct seeding) in a Spit-plot design. In Rwanda, they were planted in 2 locations, under 2 nitrogen rates (80 and 160 t ha<sup>-1</sup>) and either with or without basal application of N, as well as omission treatments of Nitrogen, Phosphorus and Potassium, in a RCBD. Result on yield stability and genotype  $\times$  environment interactions from the wide range of studied environments, will be discussed and presented.

**Keywords:** Altitude, cold, East Africa, nutrient availability, *Oryza sativa*, yield stability

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## Spikelet Sterility of Lowland Rice Related to Temperature at Booting Stage in Different Thermal Environment in Madagascar

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Rising global mean temperatures increasingly open opportunities for including crops in high altitude production systems that so far could not be grown due to temperature limitations. Lowland rice is one of those crops. Currently the window for cropping rice in higher altitudes is still quite small and thus genotypes that tolerate a certain degree of chilling to fit them into the high altitude cropping calendars, are needed. Crop growth models often allow simulating growth responses to environmental conditions if general physiological processes apply or the genotypic specific responses to those conditions are known. One prominent aspect of chilling effects in rice is cold induced spikelet sterility which is known to be depended on the temperature rice experiences during booting stage. Since crop growth models in general are based at air temperature measurements at 2 m height, since any other temperature profiles are not monitored, spikelet sterility simulations depend on air temperature measured well above the crop. However, after panicle initiation, the meristem from which the panicle develops is raised out of the irrigation water into the canopy by internode elongation. Thus, the effective temperature governing growth and development processes shifts from water to air temperature. A two years experiment was conducted in lowland rice systems in Madagascar at two contrasting altitudinal locations. Twenty varieties differing in their tolerance to cold were sown monthly in a non-replicated rice garden trial. The main objective of the study presented here was to determine the effective temperature affecting spikelet viability in high altitude rice systems. Air temperature at 2 m height, air temperature within the developing canopy and the temperature at the soil/irrigation water interface were monitored using a weather station and TinyTag dataloggers. Phenology and spikelet sterility was monitored and related to the different temperature profiles. Results show, that threshold temperatures for spikelet sterility estimated from air temperatures at 2 m height strongly overestimated the effect of temperature on spikelet sterility. Minimum soil temperature resulted in a much better fit for both spikelet sterility and threshold temperature. How to derive the effective temperature for spikelet viability during stem elongation from air temperature will be discussed.

**Keywords:** Cold stress, effective temperature, *Oryza sativa*, phenology

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## Variation in Phenological Development and Yield Performance of Rice Genotypes under Cold Stress in the Fogera Plain, Ethiopia

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Rice, *Oryza sativa* L., is the most rapidly growing food source in sub-Saharan countries in general and in Ethiopia in particular. Rice cultivation is a recent phenomenon in Ethiopia. The national average rice productivity is estimated to be 2.8 t ha<sup>-1</sup>, which is much lower than the world average rice productivity of 4.4 t ha<sup>-1</sup>. Cold stress is one of the main contributing factors for the low productivity in rain fed lowland rice production. In the study presented here, thirty rice genotypes were tested in 2016/17 cropping season in a randomised complete block design with three replications to evaluate the variability in phenological development and yield performance due to cold stress in the Fogera plain.

The weather data was recorded at 30 minutes interval throughout the cropping season. For majority of the tested genotypes, heading and flowering periods coincided with lower average minimum and maximum temperatures. We have clustered genotypes according to their phenological development and maturity period. Among the tested genotypes, the early genotypes (like Chomrhong, Machapaturi) matured in 120 days from sowing whereas the late genotypes (like WITA 4, SIM 2 Sumadil) matured in 180 days. Majority of the tested genotypes matured from 140 to 160 days after sowing. The time interval for phenological development (from 50 % emergence to maturity) varied among genotypes though they have similar maturity periods. The early genotypes showed a higher percentage of filled grains than the medium duration genotypes. Late maturing genotypes for which the heading and flowering stages coincide with night-time cold spells (less than 10°C) showed a significantly higher percentage of unfilled grain, resulting in a lower yield performance. The results of this study will help to identify potential varieties with a given maturity period to cope with the future climate variability in Fogera plain.

**Keywords:** Cold stress, genotypes, lowland rice, phenology, rain fed

## Adaptation of Fertiliser Application Strategies to Low Temperatures at High Altitudes Sites in Lowland Rice

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Rice in Rwanda is mainly produced in irrigated systems. Since Rwanda is a very hilly country rice is produced over a large gradient in altitude with the lowest production system situated at 900 m and the highest at about 2000 m asl. This results in significant differences in the thermal growth environment for rice cultivars grown at the different altitudes. However, official fertiliser application recommendations do not differentiate between growing environments 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, a basal N application could be reduced or omitted thus reducing unproductive losses of applied fertiliser. Field trials were established at two locations (900 and 1600 m asl) investigating the response of 5 contrasting rice varieties to three N application rates (80, 120 and 160 kg ha<sup>-1</sup>) with and without basal dressing and three further top dressings at mid-tillering, panicle initiation and heading. Root zone temperatures were 3.6°C lower at high altitude during the first planting date and 2.2°C during the second planting date. Duration to panicle initiation and flowering differed as function of planting dates and genotypes. Thermal conditions at high altitude site increased duration by 10–15 days depending on the genotype during the first planting date, and by 8 to 24 days during the second planting date. Thermal conditions during the second planting date increased duration to flowering by 11–14 and 1–18 days depending on the genotype at high and low altitude sites respectively. The high altitude site was the most affected by N split. Both grain yield and yield parameters were affected by N split. The omission of basal application and increase of N application at mid-tillering and panicle initiation at high altitude location have increased the number of panicles, the 1000-grain weight and grain yield; but no significant effect of N split on yield and yield components was found at low altitude site.

**Keywords:** N split, altitude, root zone temperature

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## Evaluation of Cd<sup>2+</sup> Stress Tolerance in Transgenic Rice by Overexpressing PgGPx Gene that Maintains Cellular Ion and Reactive Oxygen Species Homeostasis

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Increasing contamination and higher enrichment ratio of non-essential heavy metals induce various toxic responses in plants when accumulated above the threshold level. These effects and growth responses are genotype and heavy metal level dependent. Cadmium, a non-essential toxic heavy metal, interferes with the plant growth and development. It reaches the leave through xylem and may become part of the food chain, thus causing detrimental effect to human health. Therefore, there is an urgent need to develop strategies for engineering plants for Cd<sup>2+</sup> tolerance and less accumulation. Plant species generate a range of defense mechanisms to resist Cd<sup>2+</sup> induced toxicity and to recover the subsequent damages eliciting their genotype based biochemical responses. To counter damages plants have an efficient system of stress enzymes and antioxidant non-enzyme molecules that is termed as antioxidant system. The members of peroxidase family of antioxidant system, transport metal ions including Cd<sup>2+</sup>, and thus play important role an ion homeostasis. The present study elucidates the role of a Pennisetum glutathione peroxidase (*PgGPx*) in Cd<sup>2+</sup> stress tolerance. Transgenic rice expressing *PgGPx* showed tolerance towards Cd<sup>2+</sup> stress as demonstrated by several physiological indices including root length, biomass, chlorophyll, malondialdehyde and hydrogen peroxide content. Roots of the transgenic lines accumulated more Cd<sup>2+</sup> as compared to shoot. *PgGPx* expression in rice also protected the transgenic plants from oxidative stress by enhancing the activity of antioxidant enzymatic (SOD, CAT, APX, GR) machinery. Thus, overexpression of *PgGPx* confers Cd<sup>2+</sup> stress tolerance in transgenic lines by maintaining cellular ion homeostasis and modulating reactive oxygen species (ROS)-scavenging pathway. Thus, the present study will help to develop strategies for engineering Cd<sup>2+</sup> stress tolerance in economically important crop plants.

**Keywords:** Cd<sup>2+</sup> stress, *PgGPx*, rice, ROS

## Evaluation of Submergence Tolerance Characteristics on Nepalese Rice

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Flash flood is one of the major yield limiting factors in rice growing areas specially the South Asia. Use of the *Sub1A* gene in rice breeding enhances the tolerance for this abiotic stress in rice production. However, the identification of the new flash flood tolerant rice genes and their use in regular breeding programme is very important to enhance the efficiency of rice varietal development for future climate change hazards. Ninety five rice lines including Nepalese rice landraces, modern varieties and breeding lines were used in this study to evaluate submergence tolerance characteristics. Sambha Masuli *Sub-1* was used as resistance check while IR64 was used as susceptible check. The 14 days old seedlings were submerged in the water tank for another 14 days. The survivability was scored 7 days after de-submergence. Highest survival was observed in Sambha Masuli *Sub-1* (93.73 %), Radha-4 (89.87 %) and Sugapankhi (88.29 %). Rice landrace Sugapankhi showed good survival and regeneration ability but lacks *Sub1A-1* allele while screening using molecular markers. Increase on plant height during submergence showed the lowest survival and regeneration rate ( $r=-0.61171$ ,  $p = 0.000$ ,  $N=97$ ). Similarly, the SPAD value (leaf chlorophyll content is proportional with SPAD value) during submergence showed the positive correlation ( $r=0.429$ ,  $p = 0.000$ ,  $N=97$ ) with survivability. However, average leaf area just before submergence showed negative relationship ( $r=-0.3929$ ,  $p = 0.005$ ,  $N=97$ ) with it. Not any accession showed tillering during submergence, however, accessions with high tillering habit under normal condition showed high survival percentage during submerged condition ( $r=0.327992$ ,  $p = 0.02$ ,  $N=97$ ). Based on this study, we concluded that *Sub1A-1* allelic form is not the only one to confirm the tolerance.

**Keywords:** Leaf area, rice, SPAD, *Sub1A-1*, submergence

## **Production and Physiological Characters of Soybean under Drought Stress with Foliar Application of Exogenous Antioxidant**

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Climate change is a serious threat to the agricultural sector, and it is one of the causes of drought affecting growth and development of plants. Soybean is one of the main food protein sources in Indonesia, and drought stress may affect its production considerably. Drought stress changes physiological and biochemical aspects of plant leading to cell damage due to oxidative stress caused by increased free radical accumulation in the form of reactive oxygen species. One approach for improving the tolerance of oxidative stress in soybean under drought stress is the application of exogenous antioxidants. The aim of this research was to investigate the effect of foliar application of exogenous antioxidant on production and physiological characters of soybean under drought stress. In a factorial randomised block design two factors were studied with three replications. The first factor was drought stress with three treatments: plant watering till 80%, 60% and 40% field capacity. The second factor was foliar application of exogenous antioxidant with five treatments: no foliar application (control) or an application with salicylic acid (500 ppm), ascorbic acid (500 ppm),  $\alpha$ -tocopherol (500 ppm) or chitosan (500 ppm). The results suggest that increased drought stress conditions caused decreasing of stomatal density, total leaf chlorophyll, total leaf area, relative water content, number of filled pods, and 100 seeds weight. The effect of ascorbic acid as an exogenous antioxidant increased the total chlorophyll content of the leaves, total leaf area, number of filled pods, and relative water content, while chitosan treatment increased stomatal density only. Overall, exogenous antioxidants reduced the effects of water stress on production and physiological characters of soybean.

**Keywords:** Antioxidant exogenous, drought stress, foliar application, soybean

## Drought Effects on the Synchrony of Aboveground and Belowground Phenology of Five Potato Clones

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Literature describes the belowground and aboveground development of potato to be closely and quasi-linearly related. For example, bud formation is synchronous with tuber initiation and flowering with tuber filling. Thus, many agronomic and breeding studies in potato use non-destructive aboveground phenology to assess belowground development. No information is currently available on the influence of water deficit or salinity on the synchrony of aboveground and belowground development in potato. In order to assess the effects of water deficit on belowground development of potato it is important to know if the synchrony between aboveground and belowground development is maintained or broken. A field experiment with 5 potato genotypes was conducted between October 2013 and February 2014 in a coastal arid region of southern Peru. Plants were subjected to four irrigation treatments: fully watered, early drought (withholding irrigation 50 days after planting, DAP), intermediate (65 DAP) and late drought (80 DAP). In 5-day intervals after withholding water, detailed belowground and aboveground development was recorded.

Results showed that the synchrony between aboveground and belowground development is strongly influenced by both water deficit as such and by the development stage during which the water deficit was imposed. Whereas in early drought treatment the aboveground development appears to be faster and belowground development was retarded. The opposite was found in later development stages. Under full irrigation, on average physiological maturity of potato tubers was reached after 90 days. Stolon initiation accounted for 11 %, tuber filling for 50 % and bulking for 22 % of the time to physiological maturity under full irrigation. Under early, intermediate and late drought, tuber filling phase was prolonged over all genotypes by 5 %, 10 % and 13 % in comparison to the full irrigated control, while bulking phase was shortened. Drought also slowed down the aboveground development to flowering by a couple of days, however, there was a strong disparity between aboveground and belowground development, as aboveground phenological development appears to be slower under drought.

We highlight here the importance of investigating the aboveground development separately from the belowground development, since the assumed synchrony can be considerably affected under drought conditions.

**Keywords:** Abiotic stress, phenological development, *Solanum tuberosum*

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## Heterosis, Combining Ability and Genetic Relationship of Selected Parent Lines for Hybrid Rice Development

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Combining ability analysis is one of the powerful tools available to estimate combining ability effects and aids in selecting desirable parents and crosses for exploitation of heterosis. The performance of parents and crosses can be measured through combining ability effects. Therefore, gathering information on nature of gene effects and their appearance in terms of combining ability is essential.

In this study, the combining ability of 11 restorer lines and three widely used CMS lines was evaluated using the line  $\times$  tester mating design. It specifically aimed to (1) quantify the level of heterosis of the generated hybrids, (2) determine the yield performance of tested single cross hybrids and identify male parent with highest restoring ability, (3) determine the general and specific combining ability of 11 restorer lines and three female parents for different quantitative traits, and (4) estimate kinship among parent lines using markers. GCA and SCA effects across yield and its component were analysed. Neighbour-joining trees based on genetic similarity were constructed and were visualised in MEGA5.2

The top five hybrids namely; PR47775H, PR47774H, PR47794H, PR47800H and PR33875H were identified to have high heterotic effects and product of good line and tester combiners. Correlation analysis revealed that GCA effect and per se performance of lines had significant positive relationship. Also, lines that did not show its high per se performance to all the traits can also be a good combiner. Analysis of variance for yield and other agronomic characters showed significant difference among genotypes in days to maturity, plant height at maturity, productive tiller count, panicle length, filled grains per panicle, total spikelet count, spikelet fertility, 1000 grain weight, grain length and width, and grain yield.

**Keywords:** Combining ability, GCA effect, heterosis, line  $\times$  tester, SCA effect

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## Sorghum Hybrids - A Contribution to Future Agricultural Productivity and Food Security in West Africa

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The long-term sorghum [*Sorghum bicolor* (L.) Moench] grain yield is around one ton per ha in West Africa (WA), despite the varieties released by research. Sorghum production faces many biotic and abiotic stresses, and farmers are accustomed to use their own photoperiodic, stable and tall landrace seeds from the previous season. The International Crop Research Institute for Semi-Arid Tropics (ICRISAT)-Mali and its partners developed several experimental photoperiodic guinea-race sorghum hybrids to assess their yield and quality potential and their adoption rate by farmers. With multi-location on-farm yield trials, those tall and short hybrids were demonstrated to have respectively up to 37 and 17% of best average yield superiority over a well-adapted, farmer-preferred landrace, with taller hybrids having larger relative superiorities (up to 47%) over the local check in low-input environments. Experimental hybrids also showed little risk for farmers to recover their investment in purchased seed. Farmers' adoption of those experimental hybrids is increasing yearly (25 to 50% of farmers in villages where the seeds were produced in 2014), and farmers associations are trained to produce their own preferred hybrid seeds. A long-term hybrid-breeding programme is needed to provide WA smallholder farmers with new high-yielding hybrids that meet their low-input farming conditions and quality preferences. Presently, ICRISAT-Mali, University of Hohenheim, and partners are working on the basis of such a long-term sorghum hybrid-breeding program. This work includes, among others, mapping and validation of fertility restoration QTL for the A1 cytoplasmic male sterility system and development of new plant material for Malian and Nigerian sorghum hybrid breeding programs. This contribution aims (1) to present an overview of the work done so far and more specifically (2) to present the results of a recent study assessing combining abilities of 14 and 89 new A and R lines and corresponding hybrid performance in two-year (2015–2016) multi-location trials, conducted under two different soil phosphorus (P) levels. The outputs of this study will underline the tremendous potential of sorghum hybrids to contribute to food security in WA, and will provide sorghum breeders in WA with selection strategies for hybrid breeding targeting smallholder farmers' low input conditions.

**Keywords:** Hybrids, low input conditions, smallholder farmers, *Sorghum bicolor*

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## Morpho-Genetic Characterisation, Diversity Analysis and Evaluation of Rice Landraces in Benguet

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The study aimed to characterise rice landraces collected in Benguet based on morphological and genetic traits; determine relationships and diversity; evaluate their growth, yield and resistance to pests and diseases, grain quality; and determine the most preferred landraces based on yield performance and sensory evaluation. Fourteen Benguet rice landraces were characterised and evaluated in Kibungan, Benguet. Single nucleotide polymorphism (SNP) genotyping was done at the International Rice Research Institute-Genotyping Services Laboratory using Infinium Illumina 6K to determine their diversity analysis. Grain quality parameters were determined at the IRRI-Grain Quality and Nutrition Center. Based on 40 agro-morpho characters, 4 clusters were identified through Ward's Method. Three clusters were grouped using SNP markers. The Lamadya and Camporo group in both analyses shows their similarities on morpho-agronomic traits' expression in the field and confirmed at molecular level. Oklan cluster has a unique profile from the rest. The combination of morphological and SNP markers is reliable in discriminating these landraces. High diversity quantitative morphological traits such as leaf blade width, ligule length and flag leaf width may be used to discriminate rice landraces and as markers for future breeding programs. Low diversity qualitative traits such as leaf blade colour, auricle colour, flag leaf attitude, culm anthocyanin colour, stigma colour, presence of awn, panicle attitude of main branches, caryopsis shape and caryopsis pericarp colour may likewise be used as markers to improve yield. Based on the correlation analysis, landraces with more productive tillers or panicles have higher grain yield. But taller rice plants with thicker and longer culms, longer and wider flag leaves have lower grain yield. On grain quality, grains of most of the rice landraces have positive grain traits such as small to medium chalkiness, low to intermediate amylose content, low to intermediate gelatinisation temperature and soft gel consistency. Initial grain quality results should be tested further in replication for validity of results. Nevertheless, these results are valuable for future researches to increase yield and explore other value-addition interventions for a higher farmers' profit. Moreover, findings in this study can be used by stakeholders for rice landraces conservation and protection.

**Keywords:** Genetic diversity, landraces, single nucleotide polymorphism

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## Genetic Diversity and Structure of Wild Relatives of Sorghum Populations from Different Geographical Regions of Sudan

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Sorghum (*Sorghum bicolor* (L.) Moench) originated in East Africa specifically Sudan and Ethiopia which is considered the centre of origin of the crop where wild relatives of sorghum are widely distributed. These wild relatives harbour important genes. However they are often neglected and orphaned. Therefore, this study aimed to explore genetic diversity among and between the accessions, and the results will help with enhancing the utilisation of wild types in Sudan. 59 wild and cultivated sorghum accessions, representing three sorghum growing regions in Sudan: Gezira state (central), North Kordofan (western), and the Gadareff area (eastern). The materials were assessed for genetic diversity and population structure using a panel of 32 SSR markers. A total of 255 total allelic variations were detected for a mean of 0.6721. The Polymorphism Information Content (PIC) value averaged 0.6301 showing the polymorphic and discriminatory nature of the selected markers. The populations showed little external gene-flow. AMOVA calculated variants are lower among populations (4%), moderate within individuals (23%), and higher among individuals within population (73%). The study calculated high level of inbreeding and drift which means the wild types are isolated and/or were developed through aggressive selection in which is logically in consistent because the wild types are grown and maintained naturally. These results suggest self compatibility in wild relatives of sorghum which has not yet been explored and exploited. Wild relatives with useful traits, a broad genetic base and high diversity can be targeted in future studies using a molecular approach to restore lost genes and identify new sources of resistance.

A rooted neighbour-joining tree of four sorghum cultivars and 55 wild relatives revealed three distinct groups independent on their geographical origins. The results will be useful for future collection and utilisation in genetics and breeding programs.

**Keywords:** Genetic diversity, sorghum, SSRS markers, structure, Sudan, wild relatives

## Identification of Combining Ability Patterns for Pearl Millet Hybrid Breeding in West Africa

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Pearl millet (*Pennisetum glaucum* (L) R. Br.) is cultivated in India and sub-Saharan Africa as staple crop. Especially in West Africa (WA) it is important for the food security of smallholder farmers in rural areas. In contrast to India, breeding of hybrid varieties is still limited in WA. An extensive diversity was shown to be present in pearl millet in WA, its centre of origin. However, one major cause is the nonexistence of natural heterotic patterns as indicated by several diversity studies. The development of heterotic groups based on combining ability patterns will help to overcome this issue and make sustainable hybrid development feasible.

Population hybrids have greater population buffering capacity than single-cross hybrids, which makes them suitable to cope with harsh environmental conditions like variable inter-annual rainfall and their production requires less input and training. This increases the chance that smallholders in WA will adopt new hybrid varieties.

The objectives of this study were to evaluate combining ability, combining ability patterns and heterosis effects of WA pearl millet based on population hybrids, and to derive conclusions for developing future long-term hybrid breeding programs. Therefore, 17 populations were intercrossed in a diallel mating design. Those population hybrids were tested together with their parents at two locations each in Niger and in Senegal in two consecutive years. In addition, 21 microsatellite markers were used to evaluate genetic distances between the 17 parental populations. Results of the diallel design showed an average panmictic midparent heterosis (PMPH) of 24.2%, ranging from 0.4 to 45.7% for panicle yield. While preparing this abstract, data analysis for the diallel mating has been still underway. Results obtained so far indicate great potential for pearl millet hybrid breeding in WA. Our study represents a first step to identify combining ability patterns and initial heterotic pools for pearl millet hybrid breeding in WA.

**Keywords:** Heterotic pattern, panmictic midparent heterosis, pearl millet, population hybrids

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## Development of Hybrid Rice Variety (PR40638) with Bacterial Leaf Blight Resistance

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Bacterial leaf blight (BLB) disease is one of the most serious diseases in hybrid rice production because of the susceptibility of the parent lines and hybrids. Yield losses could cause up to 20–30% and could reach as high as 80% if susceptible plants are used. Development of resistant cultivars is an effective approach to combat bacterial blight. This study aimed to develop hybrid parent lines (PR28A and PR39902–19R56) and hybrid (PR40638) with introgressed *Xa21* gene for BLB resistance and to evaluate these breeding lines based on phenotype and genotype data. PR40638H, is an improved version of the Mestiso 3 (M3) hybrid with introgressed *Xa21* gene that confers broad spectrum resistance to BLB. Based on the evaluation, there is no significant difference between IRBB52 (resistant check) with pyramided *Xa4+Xa21* genes, PR28A (improved CMS line), PR39902–19R56 (improved restorer line), and PR40638H (improved Mestiso 3 hybrid) in terms of disease reaction against 14 isolates representing 10 Philippine races of *Xanthomonas oryzae* pv. *oryzae* (*Xoo*). The morpho-agronomic traits between the improved and original parent lines showed some dissimilarity but this could be overcome by further backcrossing. This proved the successful pyramiding of BLB resistance genes on parent lines and hybrid Mestiso 3. In terms of yield, Mestiso 3 has a maximum yield of 8.6 t ha<sup>-1</sup>, whereas PR40638H can offer a yield of as high as 9.7 t ha<sup>-1</sup> in both dry and wet seasons. This hybrid with superior yield and disease resistance could be used to increase rice production to attain rice sufficiency and increase the country's competitive advantage on the onset of Association of Southeast Asian Nations (ASEAN) economic integration.

**Keywords:** BLB, hybrid parent lines, hybrid rice, Mestiso 3, PR40638H

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# Resources and knowledge

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1) <b>Water and irrigation</b>	<b>225</b>
2) <b>Modelling</b>	<b>245</b>
3) <b>ICRAF session</b>	<b>267</b>
4) <b>Knowledge systems</b>	<b>291</b>

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# Water and irrigation

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## Oral Presentations

- PIA SCHNEIDER, BJOERN OLE SANDER, FOLKARD ASCH, REINER WASSMANN:  
**Coping with Water Scarcity: Alternate Wetting and Drying as Mitigation Strategy for Water-Shortages in a Rice Irrigation System in the Philippines.** 227
- JENS HEINKE, JENNIE BARRON, MATS LANNERSTAD:  
**Assessing the Scope for Resilient Crop Yields through Rain-water Management in Sub-Saharan Africa** 228
- WIEBKE NIETHER, ULF SCHNEIDEWIND, LAURA ARMENGOT, NOAH ADAMTEY, MONIKA SCHNEIDER, GERHARD GEROLD:  
**Reciprocal Effects of Soil Moisture Dynamics and Land-Use Systems with Cocoa in Alto Beni, Bolivia** 229
- XIALIN WANG, ERNST-AUGUST NUPPENAU:  
**A Tool of Future Trans-Boundary Water Sharing to Facilitate Land Use Transition and Poverty Alleviation in the Okavango River Basin** 230
- HELEN BERGA PAULOS, CLAUDIA RINGLER, ELIZABETH BRYAN, HAGAR EL DIDI, SARA ELNASIKH:  
**Addressing Transboundary Cooperation in the Eastern Nile through the Water-Energy-Food Nexus: Insights from an E-Survey and Key Informant Interviews** 231

## Posters

- TESFAYE BERHANU WOLDEYOHANES, ARNIM KUHN:  
**Simulating Hydro-Economic Impacts of Potential Water Rights Trade in the Lake Naivasha Basin** 232
- THOMAS FALK, SHALANDER KUMAR, SRINIVASA SRIGIRI:  
**Experimental Exploration of Institutional Transition Options for Sustainable Management of Common Watershed Infrastructure in India** 233
- EPHRAIM SEKYI-ANNAN, BERNHARD TISCHBEIN, BERND DIEKKRÜGER, ASIA KHAMZINA:  
**Whole-System Efficiency of Small- and Medium-Scale Reservoir-Based Irrigation Schemes in Northern Ghana** 234

- PETRA SCHMITTER, GEBREGZIABHER GEBREHAWERIA, SEIFU  
TILAHUN, NICOLE LEFORE, JENNIE BARRON:  
**Assessing the Effects of Smallholder Intensification through  
Improved Water Management Beyond “Business as Usual”:  
A Multi-Facet Lens on Sustainability** 235
- LUNA BHARATI, AMBIKA KHADKA, SUDHIR KUMAR, SUREN-  
DRA SHRESTHA:  
**Hydrological Analysis of Mountain Spring Systems in Nepal  
for Improved Watershed Management** 236
- ANA ALICIA DIPIERRI, DIMITRIOS ZIKOS:  
**Understanding Climate Change Impacts on Common-Pool  
Resources Management: The Case of Collective Irrigation  
Systems in Argentina** 237
- GRACE VILLAMOR, DAWIT GUTA:  
**Heterogeneity of Smallholder Farm Households Affecting the  
Water-Energy-Food Nexus in Ethiopia** 238
- SARAH GLATZLE, SEVERIN HÜBNER, MARIANA PEREIRA,  
MARCUS GIESE, ROBERTO G. ALMEIDA, FOLKARD ASCH:  
**Soil Moisture and Microclimate in Integrated Crop-Livestock-  
Forestry Systems of Central West Brazil** 239
- ALEXANDRA SCHAPPERT, ANGELA SCHAFFERT, JÖRN  
GERMER, FOLKARD ASCH:  
**Run-Off, Soil Moisture, and Weed Management Strategies to  
Increase Water Productivity in Rain-Fed Crops in Tanzania** 240
- LISA PATAECZEK, MIKENNA SMITH, THOMAS HILGER, ROLAND  
SCHAFLEITNER, ZAHIR AHMAD ZAHIR, GEORG CADISCH:  
**Impact of Deficit Irrigation on Biomass and Nitrogen Accu-  
mulation in Mungbean (*Vigna radiata* L.)** 241
- SEVERIN HÜBNER, SARAH GLATZLE, MARCUS GIESE,  
ROBERTO G. ALMEIDA, FOLKARD ASCH:  
**Field Water Dynamics in Integrated Systems in the Brazilian  
Cerrado Region** 242
- JESSICA LLOYD, IVAN LANDERS, FOLKARD ASCH:  
**Evaluation of Effect of Ridging on the Rainwater Use Effi-  
ciency of Soybean Production in Northern Ghana** 243
- MUHAMMAD TARIQ, MUHAMMAD TARIQ, PERVEZ AKHTAR,  
MUHAMMAD NAFEEES, EVA SCHLECHT, ANDREAS BUERKERT:  
**Agriculture and Water Management System in Karimabad,  
Hunza Valley, Pakistan** 244
-

## **Coping with Water Scarcity: Alternate Wetting and Drying as Mitigation Strategy for Water-Shortages in a Rice Irrigation System in the Philippines.**

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Irrigated rice consumes a large share of increasingly scarce freshwater resources and several alternative irrigation techniques have been developed with the intention to save water and maintain high yields. One of these techniques, Alternate Wetting and Drying (AWD), is increasingly applied in farmers' fields in the Philippines, where irrigation water is usually applied when the water level drops below a threshold of 15 cm below the soil surface.

WEAP ("Water-Evaluation-and-Planning"), a decision supporting tool for the management of irrigation water, has been applied in order to evaluate potential water savings of irrigated rice under AWD in the Philippines. The tool was validated for a clay and a sandy soil on the experimental station of the International Rice Research Institute (IRRI) and thereafter, applied for the Angat-Maasim-River-Irrigation-System (AMRIS), an important rice-growing area. Source of the irrigation water used in AMRIS is a reservoir, which also supplies Metropolitan Manila with 97 % of its freshwater demand. In case of water shortages, Manila's demands are prioritised and rice production is threatened.

For the IRRI experimental station, irrigation water input under conventional and AWD irrigation was simulated for 10 years using WEAP and compared to experimental data. Introduction of AWD on clay soils saved 20 % ( $\pm 9$ ) in the dry season and 11 % ( $\pm 16$ ) in the wet season, whereas on sandy soils, it saved 8 % ( $\pm 3$ ) in the dry season and 29 % ( $\pm 10$ ) in the wet season. The potential impacts of simplified scenarios of the Intergovernmental Panel on Climate Change (IPCC) and an increasing freshwater demand of Manila on the water balance of AMRIS were simulated and evaluated. The combination of both scenarios had a significant effect on the water level of the reservoir, with a 10 % ( $\pm 4$ ) larger depletion of the storage volume during the year. Moreover, inflow and precipitation were not sufficient to replenish the initial storage volume. Streamflow in the canals was reduced and could not meet the demand at the tail-end diversions. Implementation of AWD in AMRIS decreased the total water demand by 22 %. Depending on the extent of the water shortage, different temporal and spatial AWD implementation approaches are proposed.

**Keywords:** Modelling, *Oryza sativa*, water-saving irrigation, WEAP

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## Assessing the Scope for Resilient Crop Yields through Rainwater Management in Sub-Saharan Africa

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Rainfed cropping systems continue to be a major provider of food, fodder and fibre, particularly in sub-Saharan Africa where these systems cover more than 90 % of the cultivated area. However, yields are often far below potential levels. In areas with highly variable rainfall, such as semi-arid and sub-humid zones, crops are strongly affected by soil moisture constraints. This unpredictability in rainfall and soil moisture greatly increases the risks for farmers and holds back necessary investments that could enable a sustainable intensification contributing to increased harvests yields and contribute towards food security and nutrition goals.

Measures and investments in rainwater management (RWM) can overcome inter- and intra-seasonal soil moisture constraints and build resilient rainfed crop systems. This study maps where, and to what degree, rainwater management adaptation strategies can increase the resilience of rainfed crop systems to cope with rainfall variability under current rainfall regimes. The analysis uses daily precipitation data from TRMM, combined with AFSIS soil data, and a water balance modelling approach to provide daily estimates on soil moisture variability and yield impact under three different management scenarios at 0.25-degree resolution.

Results show that on 136 Mha (about 60 %) of current rainfed cropland in sub-Saharan Africa, the chance to achieve a full yield without rainwater management is less than 75 %. On about one fourth of this land (35 Mha), the risk for a total crop failure is at least 25 %. With moderate and ambitious RWM, the chances of reaching the full yield potential can be improved above the 75 % level on 35 Mha and 46 Mha, respectively. On 12 Mha, the risk for a total crop failure is reduced below 25 % under both RWM scenarios. However, even on most lands where full yields can be achieved with relatively high certainty, the implementation of RMW can help to substantially prolong the growing period and improve yields.

**Keywords:** Rainfed cropping systems, rainwater management, resilience

## Reciprocal Effects of Soil Moisture Dynamics and Land-Use Systems with Cocoa in Alto Beni, Bolivia

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Soil moisture is a function of topography, soil texture, vegetation and meteorological conditions and therefore highly spatial and temporal variable. Vegetation reduces evaporation from the soil but takes up water for production and transpiration. *Vice versa*, vegetation is affected by water availability. In many agricultural systems, especially in the (sub-) tropics with distinct dry seasons, water availability limits production. Cocoa production relies on a stable humid and warm climate. Drought causes a reduction in yield and long-term drought affects the vitality of the trees. Land-use systems with cocoa range from monocultures to highly diverse agroforestry systems. Agroforestry systems have higher water needs for the dense vegetation than monocultures, but little information is available on belowground complementarity or competition for water.

We measured soil moisture dynamics in four depths over a 30-months period in six different land-use systems, comprising cocoa monocultures, cocoa agroforestry systems and a fallow without cocoa in a long-term trial in Bolivia. By excluding the influence of topography and soil texture, we could relate the spatial variability to the land-use system. In monocultures, soil moisture was reduced in the upper 30 cm, while agroforestry systems exploited water deeper along the profile, indicating a complementarity in water use between the cocoa and the shade trees. On the other hand, soil texture and water retention capacity influenced the plant available water. In our case, the cocoa yield of the same type of production system was not affected by the soil heterogeneity.

Finally, we assessed the possibility of planting cocoa trees in a natural regrowth to maintain local biodiversity while producing cocoa. As long as the regrowth is dominated by fast growing pioneer tree species, the water use of these trees is very high and may oppress the development of the cocoa. However, in secondary forests the light will be more limiting and an adequate tree pruning and thinning would be necessary beside the water management.

**Keywords:** Agroforestry, complementarity, monoculture, spatio-temporal dynamics

## **A Tool of Future Trans-Boundary Water Sharing to Facilitate Land Use Transition and Poverty Alleviation in the Okavango River Basin**

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The Okavango River Basin (ORB) integrates three countries of southern Africa: Angola, Namibia and Botswana. Due to a poverty of the upper-catchment in Angola and Namibia, agriculture and charcoal production are prioritised for development so that the pristine forest landscapes tend to be fragmented by agriculture intensification and charcoal commercialisation, which may accelerate extract conflicts with water needs in the Botswana Delta. So far there is no such an integrated basin management that considers both trans-boundary water sharing and poverty alleviation via a sustainable transformation of land-uses. This study aims to design an innovative ecological-economic tool for representation of decision-making at the basin level in the context of payment for ecosystem services (PES), of which water volumes as Eco-System-Services (ESS) are preserved by upper-catchments benefiting the Delta, in return, payment from the Delta serves as compensation for benefit losses of the upper-catchments. We develop a spatial model of water flows in the upper-catchment of ORB from these aspects: 1) water allocation and sharing is identified as 188 successive dynamic units; 2) water availability and abstract is optimised with its economic productivity in each of all sub-basins where communities benefit from production activities through water extract over four selected land-uses: honey-producing in the forest, grazing on the grasslands, charcoal-making in the shrubs and crops in fields; 3) by introducing water pricing, the marginal utility of water is presented as monetary value to link livelihood benefits with ESS, therefore under which price the total benefit losses might be minimised; 4) livelihoods support with regard to the land-use transition is accommodated with the monetary compensation when ESS buffer will be reserved. The results indicate a water pricing institution, of which, on the one hand, a beneficial ESS will be potentially secured through the land-use change from deforestation to forest occurs; on the other hand, as a beneficiary of the ESS, the Delta will gain a retaining water provision which is even less influenced by seasonal difference of stream flows. Furthermore, the results suggest that under the wet-season water subsidy honey production has high potential to offset benefit losses of reduced intensive agricultural production.

**Keywords:** Livelihood benefits, payment for ecosystem services

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## **Addressing Transboundary Cooperation in the Eastern Nile through the Water-Energy-Food Nexus: Insights from an E-Survey and Key Informant Interviews**

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The Nile is the lifeblood of northeastern Africa, and its importance for and dependency of the national economies it traverses and binds together grows as it moves from source to sea. With rapid economic development, population growth, irrigation development, rural electrification and overall economic growth, pressures on the Nile water resources are growing to unprecedented levels. These drivers of change have already contributed to stark changes in the hydro-political regime and new forms of cooperation and cross-sectoral collaboration are needed particularly in the Eastern Nile Basin countries of Egypt, Ethiopia, Sudan and South Sudan. As direct sharing of water resources is hampered by unilateral developments, scope has increased for broader, cross-sectoral collaboration around the water, energy and food sectors. This paper uses an e-survey, supplemented with key informant interviews geared toward national-level water, energy and agricultural stakeholders, chiefly government staff and researchers, to understand challenges of and opportunities for cooperation across the water-energy-food nexus nationally in Egypt, Ethiopia and Sudan as well as regionally across the Eastern Nile. Findings from the survey tools suggest that most respondents strongly agree that collaboration across the water, energy and agriculture sectors is essential to improve resource management in the region. At the same time there is ample scope for improvement in collaboration across the water, energy and food sectors nationally. Ministries of water, energy and food were identified as the key nexus actors at national levels; these would also need to be engaged in regional cross-sectoral collaboration. Respondents also identified a wide range of actions and investments across the water, energy and food sectors – both for national and regional, joint investments. Chief investments include among these are joint planning and operation of multi-purpose infrastructure, investment in enhanced irrigation efficiency, joint rehabilitation of upstream catchments to reduce sedimentation and degradation, and investment in alternative renewable energy projects, such as wind and solar energy.

**Keywords:** Eastern Nile Basin, stakeholders, water-energy-food nexus

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## Simulating Hydro-Economic Impacts of Potential Water Rights Trade in the Lake Naivasha Basin

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The Lake Naivasha Basin in Kenya can be considered as an important social-ecological system which supports economic activities such as horticultural and floricultural production. These irrigation-based agrobusiness activities account for substantial amounts of water use and contribute immensely to the local and national GDP. The Lake is also designated as a Ramsar site for its international importance as a wetland, and supports fisheries, pastoralism, and power generation, and attracts tourists in considerable numbers. Demand for water use in agriculture is expected to increase due to population and economic growth in the region. All these economic and ecological characteristics are exposed to volatile water supply from precipitation in the Lake Naivasha Basin. As a result, management options that ensure the efficient use of water resources in the basin have become a high level policy priority. Market-based water allocation within the agricultural sector is a promising economic incentive, though less practised in sub-Saharan Africa, to increase water use efficiency and sustainability. In this study we attempt to analyse how potential water rights trade among water resources user associations (WRUAs) could affect resource use efficiency in the Basin. More specifically, we simulate the behaviour of WRUAs with respect to water and cropland allocation decisions by introducing tradable water rights, and analyse their potential economic impact under uncertain water availability. The Lake Naivasha Hydro-Economic Model (LANA-HEBAMO) is used to simulate potential water rights trade using a stochastic, recursive-dynamic simulation approach for future water uncertainty. Decentralised decisions by water users are modeled using the 'Multiple Optimisation Problem with Equilibrium Constraints (MOPEC) framework. Compared to aggregate optimisation, this modelling approach is more appropriate for policy simulations under missing or less effective water management institutions such as in the Naivasha Basin. The result from this policy simulation will provide important insights on the potential of tradable water rights for efficient water use and allocation from the developing countries perspective.

**Keywords:** Future uncertainty, Lake Naivasha Basin, water institutions, water trade simulation

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## Experimental Exploration of Institutional Transition Options for Sustainable Management of Common Watershed Infrastructure in India

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In the context of India, water is historically stored on the surface in small reservoirs which also recharge shallow groundwater aquifers. There is a strong evidence that such structures have the potential to achieve a wide range of societal goals. Nevertheless, despite its obvious potentials, many communities fail to manage structures sustainably. In the context of watershed projects the water infrastructure works well as long as there is external facilitation but cooperation in maintenance often breaks down as soon as projects come to an end.

This experimental study helps to better understand cooperation patterns in Rajasthan communities using and managing small village reservoirs. In addition, this study is intended to create awareness amongst farmers for the cooperation challenge and encourage discussions related to it. Experimental approaches have the potential to facilitate dialogue, shared learning, collective decision making, and strengthening the adaptive management capacity of local communities.

We played framed public good experiments with 300 community leaders and other local stakeholders. We introduced communication and social information in terms of revealing the players' decisions. The discussion was a critical element of our game as it allowed the players to start negotiations and propose rules. We further introduced institutional mechanisms as additional treatments.

Our results suggest that participants were able to generate solutions that are substantially better than the predictions of standard economic theory even under private decision making without communication. Introducing information and revealing the individual behaviour increases investments significantly. Players who agree to rules but also those who propose a punishment invest higher amounts. Introducing the opportunity to sanction fellow players also increased investments even though those who were punished reduced their contributions.

The discussions showed that the players connected the game to their real life experiences. They highlighted challenges but gave also examples where cooperation in the community is working well. The game sessions were a revelation for the community that led to a learning process.

**Keywords:** Common property resource, economic experiments, India, irrigation, water management

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## Whole-System Efficiency of Small- and Medium-Scale Reservoir-Based Irrigation Schemes in Northern Ghana

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The design of relevant adaptation strategies for water users in irrigation schemes in water-scarce regions of sub-Saharan Africa requires up-to-date information about the current performance of these schemes in view of rapid changes in climate and land use, population growth, and competing water demands. Many previous assessments concentrated on field-level crop irrigation but information on the schemes as the whole considering their multiple water users remains scarce. We evaluated the entire system of a small- and a medium-scale irrigation scheme shared by multiple users and included a water reservoir, water conveyance and distribution network, cropping fields, and the management entity in the Upper East region of Ghana. Multiple indicators relevant to water delivery and utilisation as well as to agricultural production during two consecutive dry seasons and the intervening rainy season were analyzed. The assessment has shown that technical factors such as underutilised reservoir storage capacity and deteriorated water delivery infrastructure strongly undermined the performance of the schemes. In particular, the medium-scale irrigation scheme utilised less than 40 % of the total storage, showing a huge need for improvement. The observations of the field-level irrigation practices suggest that an application efficiency of about 58–68 % is achievable in both irrigation schemes. The overall system efficiency can be increased from 50 % to about 68 % by reducing the large water conveyance network losses and by improving the irrigation scheduling at field level. The holistic approach considering all competing water demands is an appropriate method for performance evaluation of reservoir-based irrigation schemes in water-scarce regions.

**Keywords:** Field application efficiency, holistic performance assessment, multiple water users, overall system efficiency, small-scale irrigation schemes

## **Assessing the Effects of Smallholder Intensification through Improved Water Management Beyond “Business as Usual”: A Multi-Facet Lens on Sustainability**

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In sub-Saharan Africa small scale irrigation is developing rapidly. Whilst emphasis for development is mainly placed on water resource availability and access for irrigation, less attention is paid to adoption of water lifting and management technologies, its relation to irrigation labour, profits and long term soil fertility. The dynamics of both the nutrient and the production cycle can be significantly affected when new water lifting and management practices are introduced. The objective of this study is to evaluate the effect of different water lifting (solar, manual and fuel pumps) as well as water management methods on irrigation labour, nutrient balances and profits under supplementary and full irrigation practices of vegetables in two regions of Ethiopia. Farmers were grouped into four water management treatments: irrigation based on soil moisture monitoring, using a mechanical scheduling device (i.e. FullStop), standard crop water requirements (CWR) and traditional farmers practice (FARM). Results show that manual water lifting devices are profitable under supplementary irrigation but require best management packages, such as optimal irrigation scheduling, to boost production per ha. This in combination with viable market prices could ensure that small scale irrigation remains profitable when full irrigation is supplied. One of the main explanatory variables is the irrigation labour which is often forgotten to be a significant costing factor. Solar PV pump technologies show a high potential for Ethiopia as the labour reduced by 38 % compared to manual water lifting devices. When farmers had access to irrigation information, vegetable production using manual water lifting technologies turned into a profitable business as long as its effect on irrigation labour translated into proportional yield increases. For example, farmers increased irrigation for onion by 42 % resulting in yield increases by 85 %. However, the effect of irrigation scheduling on crop – water productivity and profits were highly variable depending on the fertiliser farmers used. Results show the importance of a recommended water management and fertiliser package to ensure sustainable intensification through irrigation development achieving crop productivity and profits gains whilst reducing potential environmental effects.

**Keywords:** Ethiopia, manual water lifting, small scale irrigation, solar, water management

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## Hydrological Analysis of Mountain Spring Systems in Nepal for Improved Watershed Management

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Springs are naturally occurring discharge features of groundwater flow systems and an important source of drinking water and irrigation in the hills and mountain regions of Nepal. Despite the importance of springs for the hill and mountain communities, a comprehensive understanding of the hydrology of these mountain spring-shed systems and their management plans is still not adequate. There is still lack of information on their occurrence, source areas, and impacts from land use activities and possible climate change. Increasing anecdotal evidence suggests that natural and anthropogenic processes are leading to the drying of springs. Therefore, under the Building Climate Resilience of Watersheds in Mountain Eco-regions project (BCRWME), a Five year field monitoring network has been set up in two study watersheds in Shikharpur and Banlek Village Development Committees (VDCs) of Far West Nepal to collect precipitation, spring and stream flow data as well as to collect samples for environmental isotope analysis. Springs in Shikharpur VDC are located between 1900 to 2500 m asl and they emerge at the contacts of phyllite and karstic limestone. Likewise, springs in Banlek VDC are located between 700 to 1100 m asl and they emerge at the contacts of colluvial soil and fractured quartzite. The stable isotopic variation in precipitation suggests that the altitude effect are -0.30 ‰ for  $\delta^{18}\text{O}$  and -1.73 ‰ for  $\delta\text{D}$ , and -0.26 ‰ for  $\delta^{18}\text{O}$  and -1.41 ‰ for  $\delta\text{D}$  for Shikharpur and Banlek VDCs respectively. Based on local geological settings and isotopic information, the recharge areas for springs in Shikharpur are located at the altitude of 994 to 1100 m asl. Likewise, the recharge areas inferred for springs in Banlek are located at the altitude of 631 to 715 masl. The preliminary results therefore suggest that a high proportion of precipitation from the previous year make up spring discharges and the spring recharge areas lie in the opposite valley for both spring sites. These results indicate that the spring recharge and watershed management programs have to extend beyond the study watersheds and cover a much larger area.

**Keywords:** Environmental isotopes, mountain springs, Nepal, spring recharge areas, watershed management

## Understanding Climate Change Impacts on Common-Pool Resources Management: The Case of Collective Irrigation Systems in Argentina

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Communal irrigations systems are composed of a natural common-pool resource, the water, which is distributed through a man-made common-pool resource, the irrigation infrastructure. Small-scale farmers are confronted with two decisions regarding the management of their communal irrigations systems: (i) how much to invest into the infrastructure maintenance and (ii) how much irrigation water to extract from the system. Moreover, environmental variations affect the timing and quantity of available irrigation water, increasing production uncertainties. Thus, small-scale farmers' dilemmas are aggravated since the uncertainty of water availability might disincentivize individual infrastructure contributions while exacerbating the likelihood of water over-extraction. This research aims at understanding how small-scale farmers manage their communal irrigations systems under environmental variations. An economic experiment originally developed for laboratory conditions was modified as a framed field experiment and was conducted to address this question. The empirical evidence from two communal irrigations systems in Northwest Argentina tested the eight hypotheses that the author proposed based on previous research findings and the pertinent literature. Some of the results were consistent with prevailing findings, while others challenged them. This thesis found that in the case under analysis and under environmental variations: investment converged; the communal irrigations systems capacity deteriorated; earnings increased; inequality decreased; cooperation improved and groups reporting low levels of institutional robustness exceeded expectations. Furthermore, this research uncovered potential strategies that could improve communal irrigations systems management under environmental variations in the area of study, while also contributing to the theoretical development of common-pool resources and communal irrigations systems in particular.

**Keywords:** Argentina, collective action, common-pool resource management, environmental variations, irrigation systems, Jujuy, small-scale farmers

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## **Heterogeneity of Smallholder Farm Households Affecting the Water-Energy-Food Nexus in Ethiopia**

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Managing the multiple tradeoffs among bioenergy use, agricultural productivity, and ecosystem functions is a major development challenge. This presentation assesses and describes the dimensions and sources of heterogeneity in relation to the dynamics of water-energy-food (WEF) nexus affecting the decisions of smallholder farm households in Ethiopia. This research activity is in accordance with the on-going research project on “Bioenergy, Food Security and Poverty Reduction: Mitigating tradeoffs and promoting synergies along the Water-Energy-Food Security Nexus” of the Center for Development Research (ZEF), University of Bonn. Its overall goal is to more sustainably manage natural resources, increase food security and reduce poverty for poor rural men and women in the face of rapid agricultural, water and energy development, and climate change problems in the Eastern Nile basin. This includes aiming to contribute in improving land, water and energy productivity in rain-fed and irrigation agro-ecosystems, and increasing the ability of low-income households and communities to adapt to environmental and economic variability, demographic shifts, climatic shocks, and long-term changes.

Although, gender is one of the aspects of heterogeneity, in this study we further explored the dissimilarities between male and female farm-households by co-developing a conceptual model of the target socio-ecological system in two major regions i.e., Amhara and Oromia regional states in Ethiopia. We used the ARDI (actors, resources, dynamics and interactions) method in the development of conceptual model as part of companion modelling, which will support in the designing of an agent-based model. Results show that there are four aspects that make the male and female farm households different such as gender specific productive roles, the perception of resource, access to external actors, and the decision to manage and utilise the resources, which may affect the dynamics of WEF nexus.

**Keywords:** ARDI approach, conceptual model, dynamics, gender, heterogeneity

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## Soil Moisture and Microclimate in Integrated Crop-Livestock-Forestry Systems of Central West Brazil

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Integrated-crop-livestock-forestry (ICLF) systems were developed to increase resource use efficiency, while at the same time these systems were attributed to be more sustainable compared to most monocultures. However, how ICLF systems affect the water balance was hardly considered so far but this aspect gained considerable attention with regard to increasing climate variability and change. In this study we measured the soil moisture and the microclimate of ICLF demonstration plots at the Brazilian Agricultural Research Corporation – EMBRAPA Beef Cattle, located in Campo Grande-MS, Brazil. Measurements were taken in four different treatments: ICLF, ICL, continuous pasture (CP) and Cerrado (native savannah vegetation). During data collection the ICLF treatment consisted of grass pasture (*Brachiaria brizantha*) lined with strips of Eucalyptus trees (*Eucalyptus urograndis*), the ICL and CP treatments consisted of *Brachiaria brizantha* and *Brachiaria decumbens* pasture, respectively. The soil moisture was monitored weekly with a FDR profile probe in the dry season (April 16 – Sept 16) and in the rainy season (Oct 16 – March 17). Microclimate parameters (temperature, relative humidity, precipitation, global radiation) were measured for each treatment. The results of the microclimate measurements indicate differences in temperature and air humidity between the treatments. The maximum temperatures for treatments with trees (ICLF and Cerrado) were lower compared to treatments without trees (ICL and CP). This can be attributed to the shading effect of trees. Regarding soil moisture, points next to the tree rows in the ICLF treatment generally had lower values compared to the central points. This could mainly be due to enhanced exploration by tree roots. Comparing the treatments, independently of the season the natural Cerrado always had the highest amount of soil moisture followed by ICL, CP and ICLF. The total amount of soil moisture for each treatments changed with the season. Spatial and temporal dynamics of the soil moisture and microclimate will be presented in detail. The natural cerrado showed the highest amount of soil moisture throughout the year indicating a higher resilience against drought compared to the land use treatments. ICLF systems should be carefully analysed with regard to their adaptive capacity against climate variability and change.

**Keywords:** Brazil, microclimate, pasture, soil moisture

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## Run-Off, Soil Moisture, and Weed Management Strategies to Increase Water Productivity in Rain-Fed Crops in Tanzania

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Smallholder crop production systems in the semi-arid Dodoma region frequently suffer from drought-induced yield losses due to inadequate rainfall distribution and erratic rainfall events. The 30 year average rainfall amount of 500 mm during the rainy-season indicates that in general precipitation is sufficient for the crops to mature. Run-off management could reduce the effects of intra-season variability in precipitation and in combination with improved weed management is likely to improve overall soil moisture availability which in turn may result in more stable yields.

The aim of this study was to analyse the potential of i) run-off management through tied-ridges, ii) minimal irrigation to keep the soil moisture above the permanent wilting point and iii) weed management to stabilise yields in pearl millet, sorghum, maize, and sunflower by improving water productivity.

Due to soil surface modification, tied-ridges (i) collect water during rainfall events and thus increase the infiltration. Minimal irrigation requirements were set to 50 % of the crop water requirements following the FAO-56 methodology and supplied via drip irrigation (ii). The weeding treatments (iii) comprised clean weeding (4–5 times weeding) and farmer's weeding practice (once after emergence and once after canopy closure).

The experiments were conducted at the Agricultural Research Institute Makutupora, Tanzania, during the wet season from January until May 2015 and 2016. Soil moisture was measured frequently using a PR2 Profile Probe. Leaf area, crop development stages, and biomass accumulation and partitioning were determined at regular intervals, and yield components were determined at harvest.

The gained dataset helped to explore the influence of differing soil moisture levels on biomass production and crop development stages. Furthermore, ANOVA with post hoc Tukey-Test ( $P \leq 0.05$ ) was analysed to evaluate the impact of run-off, soil moisture management and lower weeding frequencies on crop productivity. Tied-ridges and minimal irrigation generally increased grain yields by 80–99 % in 2015 and by 16–37 % in 2016. The yield-increasing effects were more pronounced in 2015 due to the very low yielding flat, rain-fed plots caused through insufficient rainfall amount (2015: 321 mm and 2016: 799 mm from January until May).

**Keywords:** Deficit irrigation, soil water, tied-ridges, water use efficiency

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## Impact of Deficit Irrigation on Biomass and Nitrogen Accumulation in Mungbean (*Vigna radiata* L.)

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Legumes are important nitrogen (N) contributors to cropping systems, since they are able to fix atmospheric N symbiotically. Grain legumes offer even more benefits due to grain and straw production for human and animal consumption. Using pulses for N input in a cropping system, however, requires improved accuracy of estimating N balances and N benefits for the following crop in a rotation, since grain and aboveground residues are removed at harvest. Moreover, leguminous crops are often grown in dry-land areas, exposed to water stress. This work aims at quantifying biomass and N accumulation as well as N partitioning to above and belowground parts by mungbean (*Vigna radiata* L.) under water stress.

In a controlled environment, four mungbean accessions were exposed to three irrigation treatments: recommended irrigation level (control), moderate deficit and severe deficit irrigation. Plants were harvested at maturity and dry matter and yield parameters were assessed. The stable isotope ( $\delta^{13}\text{C}/\delta^{15}\text{N}$ ) composition of above and belowground plant parts showed differences in the response to drought stress among the accessions.

Water stress did not affect pod dry weight and total aboveground biomass, but number of seeds per plant. Root biomass either increased with moderate stress and decreased with severe stress, or *vice versa*. Three accessions produced higher root biomass with severe stress (+22%) than with recommended irrigation. Root-N accumulation was dependent on the treatment: The proportion of root-N to total plant-N was similar between both stress treatments and around 30–40% of the total plant-N at maturity. The control accumulated around 20% of total plant-N in the roots. The isotopic carbon discrimination ( $\Delta^{13}\text{C}$ ) in the grain showed clear relations to water shortages. The results suggest that water stress affected N partitioning between above and belowground parts.

**Keywords:** Carbon discrimination, deficit irrigation, nitrogen partitioning, stable isotopes, *Vigna radiata*, water stress

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## Field Water Dynamics in Integrated Systems in the Brazilian Cerrado Region

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Agroforestry systems were established as a viable option for Brazilian farmers in recent decades. Shading is expected to affect the system's microclimate and thus it is likely to alter water fluxes to the atmosphere via evapotranspiration. In this study we measured the evapotranspiration (ET) with micro-lysimeters in four different treatments as a proxy for different land use systems at EMBRAPA Beef Cattle, the Brazilian Agricultural Research Corporation, located in Campo Grande-MS, Brasil. The four treatments are: Integrated systems with rows of Eucalypt (*Eucalyptus urograndis*) trees (ICLF), integrated systems without Eucalypt trees (ICL), continuous pasture (CP) and native Cerrado (Savannah) vegetation. In the ICLF and ICL plots *Brachiaria brizantha* was planted and in the CP plots *Brachiaria decumbens*. To measure the evapotranspiration lysimeters (diameter of 10 cm and a depth of 20 cm) were inserted into the ground and weighed daily during a period of 8 weeks. Within the ICLF systems, measurements were conducted in three different distances to the tree rows. In the treatments without trees the lysimeters were distributed randomly. Results were linked to data from the microclimate, i.e. wind speed, air humidity, and global radiation.

Preliminary results indicate daily evaporation at CP which was on average 1 mm higher compared to the other systems. Differences between the averages of the ICL and ICLF systems weren't significant but ET tends to be higher in the ICL system. Within the ICLF systems the measurements taken with larger distance from the tree rows showed lower daily rates of evaporation (1 mm). Differences in ET between systems were not significant due to different growth habits of the plants inside the lysimeters. Within the ICLF systems lysimeters with largest distance to trees showed lower ET which an average difference of 3 mm. With higher wind velocities and lower air humidity the difference increases. The differences in ET and microclimate are probably a result of lower grass canopy densities close to the tree rows and on CP. This management effect on unproductive water losses via evaporation should be considered in the context of site productivity, system's resilience against drought, and resource use efficiency.

**Keywords:** Brazilian savannah, evapotranspiration, micro-lysimeter

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## Evaluation of Effect of Ridging on the Rainwater Use Efficiency of Soybean Production in Northern Ghana

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As climate change continues to influence rainfall patterns, it is causing frequent and more intense rainfall events, directly influencing the future of agriculture. Social-ecologically, a shift in land management practices, specific to soil ridging rather than conventional tillage/flattening could help minimise these severe rainfall events impact. Fluctuations in soil moisture due to the variability in rainfall must be stabilised in order to create an efficient crop production system. Soil ridging promotes the soils ability to allow water to infiltrate, have ideal permeability and water holding capacity – both necessary capabilities a soil must have in order to maintain consistent, proper moisture content.

The objectives of the research were to see if a) stabilisation of soil moisture could be achieved via soil ridging and b) to determine if the stabilisation of soil moisture content caused a significant difference in soybean yield compared to conventional soil preparation.

The experiment was carried out during the 2016 cropping season in the Chereponi District of Ghana's Northern Region. The ridges constructed were able to evacuate water during times of heavy rainfall whilst the troughs maintained higher soil moisture content during periods of brief drought, as compared to adjacent non-ridged plots. It was found that over the 14 trial fields ridging produced an average yield of  $1603 \text{ kg ha}^{-1}$  ( $\text{SEM} \pm 161$ ) while non-ridged plots produced only  $1258 \text{ kg ha}^{-1}$  ( $\text{SEM} \pm 142$ ). The differences in yield could be evidence of greater root penetration and nutrient scavenging, accredited from not only the increased water infiltration created by the soil ridges but also soil de-compaction which occurred during ridge formation.

**Keywords:** Ghana, soil ridging, soybean

## Agriculture and Water Management System in Karimabad, Hunza Valley, Pakistan

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To understand the water governance system in a typical settlement of the Central Asian Karakorum Mountains primary data on agricultural water management systems were collected through field survey, in-depth interviews, focal group discussions, field measurements and semi-structured questionnaire covering 110 households selected by a snowball sampling scheme in Karimabad, Pakistan. People of Karimabad depend on water received from Ultar Glacier to irrigate their crops and fruit gardens. Each of the four selected zones received irrigation water for three days and two nights or two days and three nights. The cultivated land was categorised into three classes cropland (*Sehin*), orchard land (*Baseo*) and grassland (*Toq*). Irrigation priority was given to cropland followed by orchards and grassland. Among four main water channels discharge rate was highest ( $46.73 \text{ m}^3 \text{ sec}^{-1}$ ) in Dallah, followed by Barba, Hamachi and Dilbar. It was also observed that recently traditional double crops patterns were replaced by the establishment of cash crops. For household consumption there is a separate water supply system that supplies water from time to time. In case of water shortage everyone is allowed to collect water from a particular channel. *Jirga* and *Nambardars* (selected persons (four) from each tribe) play a very important role in water distribution and water disputes. 86% of the respondents confirmed that distribution of water is managed by the *jirga*. Which also solved disputes on irrigation water. Farmers depend upon fruit production as a major source of income ( $P \leq 0.001$ ) but the production and sale of vegetables also plays an important role for the household income. The data also indicate that Karimabad has experienced major socio-economic and agriculture changes in the last three decades whereby population growth and intensive agriculture in water deficient periods are main causes for water scarcity.

**Keywords:** Agriculture system, crops rotation, gravity fed irrigation, Hunza, water scarcity

# Modelling

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## Invited Paper

- EIKE LUEDELING, CORY WHITNEY, TODD ROSENSTOCK,  
KEITH SHEPHERD:  
**Modelling Agricultural Realities to Support Development  
Decisions** 248

## Oral Presentations

- CARSTEN MAROHN, RAINER WEISSHAIDINGER, GIAN  
LINARD NICOLAY, ABIGAELO OTINGA, ALEX POHL, ROEL  
MERCX, RUTH NJOROGI, ERIC KOOMSON, FRANCIS KERRE,  
JANE WANGARURO, SAMUEL NJOGO, BERNICE MUNINI,  
GEORG CADISCH:  
**A Framework of Biophysical Measurements, Innovation Plat-  
forms and Modelling for Agricultural Stakeholders' Land-  
scape-Scale Decisions** 249

- PERRIHAN AL-RIFAI, MD ALAM HOSSAIN MONDAL, TINGJU  
ZHU, CLAUDIA RINGLER, CLEMENS BREISINGER, EL DIDI  
HAGAR:  
**Linking the Economics of Water, Energy, and Food: A Nexus  
Modelling Approach for Egypt, Ethiopia, and Sudan** 251

- BENJAMIN WARTH, CARSTEN MAROHN, FOLKARD ASCH:  
**Assessing Savannah Grassland Intensification Impacts –  
Integrating Vegetation Community Functions into  
Physiological Crop Models** 252

- LOTTA CLARA KLUGER, MATTHIAS WOLFF:  
**Social-Ecological Transition from Open Access Fishery to  
Successful Aquaculture: The Case of the Peruvian Scallop** 253

## Posters

- ERIC KOOMSON, TARIRAI MUONI, CARSTEN MAROHN, ALAN  
DUNCAN, INGRID ÖBORN, GEORG CADISCH:  
**Measuring and Modelling Soil Loss and Runoff Mitigation  
Potential of Legume-Led Crop Rotations under Varying  
Slope Lengths in a Small SW Kenyan Catchment** 254

- HONGXI LIU, XUEQING YANG, SERGEY BLAGODATSKIY, CARSTEN MAROHN, MARCUS GIESE, GEORG CADISCH:  
**Climate Change Impacts on Erosion Control in a Watershed with an Integrative Modelling Approach** 255
- EEUSHA NAFI, THOMAS GAISER, ISAAC DANSO, HEIDI WEBBER, JESSE B. NAAB:  
**A Multi-Model Ensemble Approach to Assess the Effects of Alternative Management Practices on Soil Properties and Crop Yield** 256
- WENZHI ZENG, GUNTHER KRAUSS, THOMAS GAISER, BABACAR FAYE, STEFAN SIEBERT:  
**Development, Calibration, and Validation of an Intercropping Model** 257
- THANH THI NGUYEN, MELVIN LIPPE, CARSTEN MAROHN, VIEN DUC TRAN, GEORG CADISCH:  
**Assessing Impacts of Long-Term Maize-Cultivation Using the ‘Dynamic of Total Carbon and Nitrogen Distribution’ Model** 258
- FESTO RICHARD SILUNGWE, FRIEDER GRAEF, SONOKO DOROTHEA BELLINGRATH-KIMURA, MARCOS A. LANA, SIZA TUMBO, FREDERICK C. KAHIMBA, ELIREHEMA SWAI:  
**Evaluation of Spatio-Temporal Rainfall Variability and its Implications on Pearl Millet Production in Semi-Arid Areas** 259
- KOKOU ADAMBOUNOU AMOUZOU, JESSE B. NAAB, JOHN LAMERS, PAUL L. G. VLEK, MATHIAS BECKER:  
**Yields and Water Use Efficiency of Maize and Sorghum under the Impacts of Climate Change in West Africa** 260
- KHALID HUSSAIN, AYESHA ILYAS, ASHFAQ AHMAD, THOMAS HILGER:  
**Agro-Forestry: A Sustainable Cropping Option for Uplands in Western Thailand** 261
- FLORENT NOULEKOUN, JESSE B. NAAB, JOHN LAMERS, NI’MATUL KHASANAH, MEINE VAN NOORDWIJK, ASIA KHAMZINA:  
**Simulating the Growth Dynamics of Afforestation Species under Climate Change Impacts in Northern Benin** 262
- CHARLOTTE KOTTUSCH, JASMINE PUTERI, PING YOWARGANA, LINDA SEE, SABINE FUSS, SONYA DEWI, ALINE MOSNIER, FERNANDO RAMOS, GILBERTO CÂMARA, NIRATA SAMADHI, ZULFIRA WARTA, PAUL CHATTERTON, FLORIAN KRAXNER:  
**RESTORE+: A New Methodology for Addressing Landscape Restoration on Degraded Land (in Indonesia and Brazil)** 263

DIANA XIMENA JAIME ACEVEDO, JOHANNES MÖSSINGER, THOMAS BERGER: <b>Participatory Mathematical Farm Programming - A Management Tool for Smallholders in Transition</b>	265
ANDREA GONELLA JIMENEZ, TOBIAS WÜNSCHER, JAN BÖRNER: <b>Modelling the Opportunity Cost of Reforestation in the Upper East Region of Ghana</b>	266

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## Modelling Agricultural Realities to Support Development Decisions

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Most agricultural models do not adequately represent real-life development decisions, not least because they fail to consider the impact of the full range of biophysical, socio-economic, political and cultural factors that affect decision outcomes. Many modelling exercises restrict their scope to system aspects that can be characterised with precision, but this can lead to biased recommendations. For instance, only considering annual crop yields while neglecting ecosystem services provided by trees systematically undervalues agroforestry systems. Similarly, crop models that only consider abiotic factors but leave out pests, weeds and diseases may favour crop varieties that fit poorly in smallholder farming systems. To produce more holistic assessments that respond to the needs of development decision-makers, agricultural modelling needs new strategies that enhance its ability to deal with real-world complexities and allow capturing system aspects that defy precise quantification. Decision analysis, a decision-support approach from the private sector, aims to make recommendations for specific decisions based on currently available knowledge. To gain a holistic perspective, it starts with an assessment – often involving decision-makers, stakeholders and experts – of all decision-relevant aspects and their interconnections. Results from this assessment are translated into causal decision models, in which all factors are considered in quantitative terms, represented using probability distributions. For each input variable, all available sources of information, including hard data and expert opinion, are used to construct the distributions. Simulations produce probability distributions expressing the range of plausible decision outcomes. These outputs are often sufficient for identifying preferable decision options. If not, tools such as Value of Information analysis are used to highlight critical knowledge gaps where further information is needed to reduce uncertainty and clarify the best decision alternative. Decision analysis approaches are new to agricultural research for development, but several successful applications across Africa, e.g. forecasting the impacts of agricultural interventions in Kenya or prioritising among strategies for reservoir protection in Burkina Faso, have underscored their potential. Experiences so far indicate that decision analysis could emerge as a new paradigm for holistic, decision-focused agricultural modelling.

**Keywords:** Bayesian modelling, decision analysis, holistic modelling

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## A Framework of Biophysical Measurements, Innovation Platforms and Modelling for Agricultural Stakeholders' Landscape-Scale Decisions

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Low productivity of non-responsive soils, limited land for cattle grazing to produce sufficient manure and lacking financial resources for fertiliser substantially limit food production and threaten food security in many densely populated areas not only of western Kenya.

Legume-led crop rotations and intercropping have been promoted by many projects, but have not been well-adapted nor adopted. Crop-livestock integration has been suggested as possible improvement but in the absence of sufficient land and of proper manure management, animals usually compete with soils for plant residues.

While many technical biophysical solutions work in principle or under specific settings, they need acceptance by those to implement them. This becomes even more complex as farm-scale solutions need to be upscaled to the landscape level, where collective action or access to decision-makers are crucial. We present the interdisciplinary approach of the CONNESSA consortium (CONNEcting knowledge, scales and actors; An integrated framework for adaptive organic resource management, targeting soil aggradation and agroecosystems' resilience in SSA) illustrated by a case study in Kenya.

We follow a flexible site-specific sequence of biophysical field experiments, innovation platforms (IP) and modelling exercises to derive policy recommendations. The case study included field experiments at three sites in western Kenya, replicated at four farms per site on effects of manure and fertiliser combinations on maize and legume yields; experimental data were later employed for modelling. Crop-livestock integration, legume-based soil conservation and tree planting scenarios were formulated by farmers, extension officers and NGO during an IP at one site, Sabatia.

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Scenarios were simulated over various years for a 20 km<sup>2</sup> watershed using the Land Use Change impact Assessment tool (LUCIA). Model results were evaluated during a second IP followed by another round of more in-depth modelling.

We discuss in how far the combined modelling-IP approach can inspire stakeholders' development scenarios and lead to better ownership / acceptance of suggestions and improved collective action. Parallels and contrasts between Sabatia and a twinned case study in Burkina Faso are shown in order to derive generic conclusions.

**Keywords:** Actors, connecting knowledge, innovation platforms, landscape modelling, scales, soil degradation

## Linking the Economics of Water, Energy, and Food: A Nexus Modelling Approach for Egypt, Ethiopia, and Sudan

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By 2050, global food security will face significant challenges from climate change, global population pressures (expected to surpass the nine billion mark), and increased urbanisation. The recently adopted Sustainable Development Goals call for progress on key dimensions of human development and environmental sustainability. However, as a result of growing natural resource scarcity, making progress in one area, such as food security, will likely adversely affect progress towards desired outcomes in other areas, such as water security or environmental sustainability. Thus, business as usual approaches are no longer an option. Instead, advances in food security need to be addressed within a nexus perspective incorporating key interlinkages with related sectors, including water and energy. We use an innovative methodology (composed of three models) to model the socio-economic linkages between water, energy, and food in the Eastern Nile Basin. The modelling framework consists of a biophysical representation of the natural resource base, including water, an energy systems mode and a computable general equilibrium model. The biophysical component model combines a hydrological model, a river basin management model, and a crop model. The energy component model uses the MARKAL/TIMES energy model and finally, the socio-economic component model connects the energy and biophysical components through a country-specific dynamic recursive computable general equilibrium model, allowing us to analyse the impacts of changes in water and energy supply on the economy as a whole and on poverty and income distribution in particular, all the while exploring policy scenarios for action and for potential synergies that may present themselves. Based upon a theoretical nexus framework, the methodology is expanded into a quantifiable modelling suite that underlies the analysis of three country case studies; Egypt, Ethiopia, and Sudan. The modelling framework is then used to examine the impact of climate change on changes in tradeoffs among water, energy and food security in the region into the future followed by alternative investment scenarios in irrigated agriculture as well as in conventional and alternative energy sources to assess water, energy and food security implications and identify policies and institutions to ensure that the needs of the poorest can be met.

**Keywords:** CGE, climate change, MARKAL/TIMES, Nile basin, welfare

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## Assessing Savannah Grassland Intensification Impacts – Integrating Vegetation Community Functions into Physiological Crop Models

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Economists see high potential to increase agricultural productivity in African savannahs through rangeland intensification and conversion into cropland. Ecologists however expect negative impacts on ecosystem services (ESS) such as soil and vegetation degradation, which threaten the ecological and economic sustainability of the system. Vegetation structure and its changes play a crucial role in this context and models have been employed to simulate long-term and probabilistic processes. Ecological vegetation models simulate plant type assembly dynamics, but usually based on empirical relationships, lacking processes behind takeover and suppression of different plant functional types. The mechanistic level of physiological crop models however allows exploring these processes, but rigid spatio-temporal pattern of growth and plant interaction limit its applicability for grassland simulation. This study aims to provide a concept to integrate ecological grassland vegetation functions into process-based crop models. Two substantial limits of crop models were identified: (1) Plant interaction on plot level is defined by explicit or zonal canopy and rootstock overlaps due to homogeneous row arrangement, whereas savannah vegetation has a stochastic to patchy spatial structure. (2) Crop models are able to reflect major disturbance impacts via dry season/drought effects and simple grazing mimicking slash-and-remove functions, but they lack carbohydrate reserves supporting survival during and regrowth after disturbances.

To resolve these limitations, (1) on grassland plots, crop model's row geometry is dissolved to represent random plant arrangement, where spatially inexplicit interaction between plant types starts when total vegetation ground cover exceeds 100 percent. An additional clumping factor accounts for interactions occurring before 100 percent ground cover is reached, reflecting patchy vegetation. (2) The growth of carbohydrate reserves is supplied by excess assimilates which are not needed for plant growth when the latter is limited by phenological development. Reserves are remobilised to support regrowth after grazing and drought as well as to allow plant survival by compensating net respiration during dry periods.

We developed and tested a 'minimum-invasive' concept of amending physiological crop models where two additional functions – heterogeneous plant arrangement and regeneration capacity - allow the mechanistic representation of major plant type assembly processes in savannah grasslands.

**Keywords:** Disturbance impacts, pasture regrowth, patchy vegetation structure, plant interactions, process-based modelling

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## Social-Ecological Transition from Open Access Fishery to Successful Aquaculture: The Case of the Peruvian Scallop

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Mariculture is becoming increasingly important for aquatic food production, as an alternative to exploiting natural populations. Bivalve culture represents a sector of particular economic potential and environmental friendliness, because cultured individuals feed on naturally occurring phytoplankton at the bottom of the food chain, reducing production costs and environmental impacts. The Peruvian bay scallop *Argopecten purpuratus* is a key resource targeted along the Peruvian and Chilean coastline since the 1950's. In Sechura Bay (North Peru), an open-access multispecies diving fishery was recently transformed into a property-rights-based mariculture regime. While scallop production declined in other locations to the South, the bay developed into a hotspot. About 25000 persons are currently involved, representing the most important socio-economic activity in the region. A socio-ecological analysis suggests that the combination of favourable environmental conditions and low production costs have facilitated the rise in scallop production in Sechura. Small-scale scallop farmer cooperatives were the ones initiating the establishment of aquaculture operations, holding the decision power with respect to scallop grow-out and harvest. This bottom-up approach allows for a lasting, sustainable performance of the activity. However, today's single-species dependence is likely to increase the system's vulnerability to international scallop market price fluctuations and environmental disturbances. The sustainability and resilience of the system thus depends on successful ecosystem-based management and the ability of local stakeholders to cope with disturbances. A social-ecological network model based on interactions among different actors was constructed. Preliminary results include the identification of key groups and pathways, and the exploration of different environmental and management scenarios for the prediction of tipping points and points of leverage to render the system more resilient. Hereby, this work helps to better understand feedback mechanisms between scallop mariculture, ecosystem health, and people's well-being, and the effects of management measures to improve the resilience of the overall social-ecological system.

**Keywords:** Fisheries transformation, natural resource management, network modelling, social-ecological systems, sustainable aquaculture

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## Measuring and Modelling Soil Loss and Runoff Mitigation Potential of Legume-Led Crop Rotations under Varying Slope Lengths in a Small SW Kenyan Catchment

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Soil erosion is a major constraint to crop productivity in southwestern Kenya where agricultural activities are mostly spread on hilly terrains. In smallholder-dominated Rongo sub-county soil erosion has reportedly changed the soil properties in the entire landscape. Land tenure is conventionally structured in slope direction and predominant maize plots are ploughed downhill. Soil erosion is determined non-linearly by slope length, hence spatial arrangement and positioning of crops should be of great concern. We posited that placement of soil erosion conservation measures at different slope locations affects the total amount of soil and nutrient loss on that slope and in the landscape. This was tested by a) field measurements of run-off and erosion on 12 m × 4 m RCBD plots under different legume ground cover (*Mucuna pruriens*, *Lablab purpureus*, *Arachis hypogaea*) planted in pure stand and *Zea mays/Phaseolus vulgaris* intercrop (farmers' practice) with and without mulch; b) *Zea mays/Phaseolus vulgaris* intercrop on bounded plots of 20, 60, and 84 m length at different locations in the landscape; c) a modelling approach using the landscape model LUCIA (Land Use Change Impact Assessment). Field experiments showed that *Mucuna pruriens* decreased runoff and soil loss most effectively after the mulch treatment, followed by *Lablab purpureus* and *Arachis hypogaea*. Highest runoff and soil loss was observed under *Zea mays/Phaseolus vulgaris* intercrop. Slope length influenced runoff, and larger soil loss was observed on the longer slope lengths. LUCIA was calibrated and validated with the 1-year field datasets on runoff and soil loss. Model scenarios are led by maximising food crop and fodder use whilst reducing nutrient loss on cropped fields and avoiding siltation of fish ponds and streams in the lower watershed parts. Regarding sediment loads at the watershed outlet, uphill soil conservation measures during first simulations proved more effective than filter strips along streams, but growth of some legumes may be restricted by soil moisture on the upper slopes. Modelled best practices of legume-based soil conservation will be extended to the landscape scale. We will discuss aspects of implementation of soil conservation measures by farmers at the landscape scale.

**Keywords:** Landscape, legume, LUCIA, modelling, scenario, slope length, soil erosion

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## Climate Change Impacts on Erosion Control in a Watershed with an Integrative Modelling Approach

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In this study we applied a landscape based soil-crop/tree integrative model (Land Use Change Impact Assessment, LUCIA) and investigated the efficacy of erosion control measures in rubber plantations under increased precipitation and temperature based on existing climate change scenarios. The model was firstly calibrated and validated at plot level to simulate weed management (“no-weeding”, “once-weeding”, “twice-weeding” and “clear-weeding”) effects on soil loss in rubber plantations. Subsequently, the model was calibrated to simulate total sediment yield in a small watershed (. ha, or km<sup>2</sup>) located in Xishuangbanna, South-West China, where rubber plantations occupy around 15 % land use in this watershed. Model outputs suggested that total soil loss in the watershed decreased by 15 % with reduced herbicide application in rubber plantations. Scenarios of climate change were further applied in the model to assess response of erosion control measures to increasing precipitation and temperature: 1) ‘baseline’ with rainfall and temperature measured in 2014; 2) ‘R+’ with rainfall amount increased by 2.6%; 3) ‘T+’ with temperature increased by 2.4°C; 4) ‘RCP (representative concentration pathways) 8.5’ with rainfall increased by 2.6 % as well as temperature by 2.4°C. Modelling results indicated that increasing temperature (‘T+’) decreased soil litter cover by accelerating decomposition. This affected soil loss to higher extent than increasing rainfall (‘R+’) at both plot and watershed level. Soil loss in rubber plantation increased from 2 t ha<sup>-1</sup> to 3 t ha<sup>-1</sup> under “twice-weeding” due to increasing precipitation and temperature; while reduced herbicide application (“no-weeding” and “once-weeding”) kept soil loss below 1 t ha<sup>-1</sup>. Total sediment yield in the watershed increased from 800 t a<sup>-1</sup> to 1130 t a<sup>-1</sup> by increased precipitation and temperature under current management but was reduced 960 t a<sup>-1</sup> under reduced herbicide in rubber plantations. The results of this study suggest that management has the potential to mitigate soil loss by climate variability or change.

**Keywords:** Climate change, erosion control, modelling, rubber plantation, watershed



## A Multi-Model Ensemble Approach to Assess the Effects of Alternative Management Practices on Soil Properties and Crop Yield

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Decline in agricultural production due to the growing population and soil degradation has become a major concern in Sudan Savannah as it threatens food security that reportedly will trigger a change in food habits as well as demanding even more food. Therefore, it is important to check soil degradation in order to ensure a sustainable production system. To counteract the problem of soil degradation, alternative management practices can be adopted that has potential to prevent and/or reduce the severity of soil degradation as well as to improve the production system in a sustainable manner. For this purpose, a study has been established which compares possible technical approaches to evaluate the effect of soil and crop management options on soil degradation; (1) experimental (short-term effects), and (2) model simulation (long-term effects). The experimental approach includes field trails to test the effects of contour ridge (CR), reduced tillage (RT), and crop residue management (CRM) on soil properties and crop yield. In order to assess their impact at long-term and to identify the best management practice, use of model simulations has become a more appropriate trend. The models which show best validation results based on the five years field-experiment will be used to anticipate the long-term performance of technologies and eliminate the need of conducting tedious long-term experiments. Hence, this study intends to validate three different crop models (SIMPLACE (Scientific Impact assessment and Modelling Platform for Advanced Crop and Ecosystem management) model framework, EPIC (Environmental Policy Integrated Climate), DSSAT (Decision Support System for Agrotechnology Transfer)) to predict the single and combined impact of tillage and crop residue management on soil quality and crop yield. Having such a good number of crop models that include the effects of tillage and crop residue management on crop yield and soil properties, we will perform an ensemble modelling approach, which denotes a comparative evaluation of the models to perceive the accuracy of the model simulation and to evaluate the uncertainties during the simulation.

**Keywords:** Crop residue management, ensemble modelling, soil degradation

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## Development, Calibration, and Validation of an Intercropping Model

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Intercropping is an agricultural practice of cultivating two or more crop species simultaneously in the same field. Compared to sole cropping, main advantages of intercropping are an increase of the interception of solar radiation and increased nutrient supply when legumes are integrated into the intercropping system, resulting in increasing crop growth. Intercropping is presently used in many tropical and subtropical regions. However, due to the spatial heterogeneity of the intercropping system and complexity of belowground competition for water and nutrients, it is challenging to dynamically simulate intercropping. Here we present a new intercropping model that was developed by integrating different modules such as light interception, belowground allocation, soil water movement and crop growth using the Scientific Impact assessment and Modelling Platform for Advanced Crop and Ecosystem management (SIMPLACE) framework. We firstly checked the plausibility of three different approaches and selected the optimal one to describe light interception between two intercrops, then proposed an allocation strategy for belowground resources considering both alive root length density and crop water demand. The model advances previous attempts of intercropping modelling by simultaneously considering aboveground competition for light and belowground competition for water and nutrients together of different intercropping arrangements. Field experiments including five different intercropping arrangements were conducted in Dassari, Burkina Faso in 2015 and 2016 and used to calibrate and validate the model. The results indicate that our model performs accurate simulations for both biomass and plant height in intercropping arrangements without legumes (e.g. sorghum-maize) in both 2015 and 2016. The accuracy for arrangements including legumes (e.g. cowpea) should be further improved by a better representation of dynamics in symbiotic N-fixation.

**Keywords:** Competition, intercrops, Lintul 5, modelling, SIMPLACE

## Assessing Impacts of Long-Term Maize-Cultivation Using the ‘Dynamic of Total Carbon and Nitrogen Distribution’ Model

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Ongoing population growth spurred the demand of agricultural land further accompanied by agricultural intensification in Northwest Vietnam. This trend led to an expansion of mono-maize cultivation areas to steep sloping environments with the result of severe soil degradation. Against this background, the presented study evaluated the development of soil fertility under mono-cropped maize cultivation in Northwest Vietnam to offer decision support for natural resource management at watershed level. The specific objectives were: (1) determining the dynamics of total Nitrogen (NTot) and Carbon (CTot) under current maize cultivation regimes along selected transect gradients, and (2) developing the spatially-explicit Dynamic of total Carbon and Nitrogen Distribution (DyCNDiS) model to assess potential impacts of CTot and NTot development after long-term and intensified maize cultivation patterns using Chieng Khoi watershed as an example.

Three transects were delineated to assess NTot and CTot content in topsoil along a 25–30 m slope gradient, and to determine crop history focusing particularly on the duration of maize cultivation period. Building on transect results and further auxiliary data, the spatially-explicit DyCNDiS model tool was developed using the relationship of cultivation time and C/NTot content as basic modelling unit. After successful model validation, DyCNDiS was used for a soil degradation hotspot analysis, aiming to identify those areas at watershed-level which have the highest risk of soil degradation under the current mono-cropped maize cultivation regime.

DyCNDiS identified 134 ha of hotspot areas that are prone to soil degradation after 20 years of continuous maize mono-cultivation, accounting to 19 % of the total 708 ha of upland cultivation areas in Chieng Khoi watershed. DyCNDiS suggested that particularly those areas require increased attention by government authorities and local farmers, calling for soil conservation measures to retain soil fertility in the long run.

**Keywords:** Carbon, long-term maize, model, nitrogen

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## Evaluation of Spatio-Temporal Rainfall Variability and its Implications on Pearl Millet Production in Semi-Arid Areas

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Improving knowledge on spatio-temporal rainfall variability and its influence on small farmers' agricultural crop production strategies enables mitigating climate change and preparing upgraded adaptation strategies in rainfed agriculture.

We measured rainfall for 50 different spatial locations over an area of 12.5 km<sup>2</sup> in Idifu village, in the semi-arid Dodoma region of Tanzania for the season 2015/2016 and 2016/2017. Using K-Means Algorithm for Clustering method and QGIS, existing rain gauges and new rain gauges were positioned to a centroid to cover the area of influence of approximately 250,000 m<sup>2</sup>. The average distance between rain gauges was approximately 500 m. CROPWAT model was used to calculate the daily and decade crop evapotranspiration (ET<sub>c</sub>) of pearl millet in that study area for each month during the growing season. The amount of daily rainfall collected at different positions in the village for each month was compared to the calculated crop evapotranspiration to determine the ET<sub>c</sub> deficits in each particular location.

The results show that the total ET<sub>c</sub> of pearl millet in the area on average is 527 mm which was higher than the average amount of rainfall of the area for both seasons. However, both rainfall and ET<sub>c</sub> deficits vary spatially in that small agricultural watershed significantly ( $p < 0.05$ ) within a short distance. The daily rainfall variability is by far higher than the monthly and seasonal variability. This explains the high variability and risk of crop failure since the amount of rainfall deficit which highly affects the crop growth and production is the daily rainfall deficits as compared to the monthly and the season rainfall.

Farmers have adapted to these conditions by using crop management strategies such as dry-seeding, re-seeding, transplanting and spatially distributing their fields across larger areas. Still they have been repeatedly suffering from crop failures during the last years. Other strategies are therefore required and are being tested to reduce the effect of daily rainfall variability. Infield rainwater harvesting such as tied ridges and ponding pit cultivation may act as means for extending favourable soil moisture conditions and hence reduce the acuteness of the spatio-temporal rainfall variability.

**Keywords:** Crop water requirement, CROPWAT model, farmers' management strategies, pearl millet, rainfall, spatio-temporal variability, watershed

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## Yields and Water Use Efficiency of Maize and Sorghum under the Impacts of Climate Change in West Africa

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Increasing warming, recurrent dry spells, and land degradation represent serious threats to sustainable development in West Africa. The climate-driven changes in soil water and nutrients will put at risk the resilience of the production systems, but one remains uncertain about the magnitude in this region, including northern Benin. This study examined the responses of maize and sorghum to three soil fertility management options (control, integrated soil-crop management, high mineral fertiliser use) under historic climate (1986–2005) and compared these to the performance of the same options under bias-corrected ensemble predictions (BNU-ESM, CanESM2, and MPI-ESM-MR models) of future climate (2080–2099) for three Representative Concentration Pathways (RCPs, 2.6, 4.5, and 8.5). The climate datasets served as inputs in the previously calibrated and evaluated CERES-Maize and CERES-Sorghum Cropping Systems Models. The ensemble of the climate models predicted seasonal rainfall variability reaching  $-2\% \pm 6$ ,  $-4\% \pm 8$ , and  $+1\% \pm 9$  for RCPs 2.6, 4.5, and 8.5, respectively. Changes in temperature depicted increasing warming trends in minimum temperature of  $+1.0 \pm 0.2$ ,  $+2.0 \pm 0.2$ ,  $+4.7^\circ\text{C} \pm 0.4$  and maximum temperature of  $+1.1 \pm 0.2$ ,  $+2.0 \pm 0.3$ ,  $+4.6^\circ\text{C} \pm 0.5$ , for RCPs 2.6, 4.5, and 8.5, respectively. The ensemble simulated a decrease in solar radiation by about  $-0.4 \text{ MJ m}^{-2}\text{d}^{-1}$ . CERES-Maize predicted a larger increase in the dynamics of aboveground biomass at the season onset but a decrease later in the cropping seasons, with largest changes under RCP8.5. CERES-Sorghum simulated similar patterns, but the decrease in biomass accumulation would occur earlier in the season under RCP2.6 and 4.5 than with RCP8.5. The assumed future climates reduced maize biomass yield by 11–29%, grain yield by 10–46%, and water-use efficiency by 17–53%. CERES-Sorghum predicted decreases by 21–47% for biomass yield, 22–51% for grain yield and 23–51% for water-use efficiency. The largest depressive effects were predicted under RCP 8.5. With an integrated soil-crop management and high mineral fertiliser use, maize response was relatively resilient to climate change under RCP2.6 and 4.5. It is concluded that a stabilisation of the warming below  $2^\circ\text{C}$  remains critical for achieving benefits from sustainable intensification efforts in major production systems in West Africa.

**Keywords:** Climate scenarios, crop production, CSM-CERES, resource use efficiency, *Sorghum bicolor*, *Zea mays*

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## Agro-Forestry: A Sustainable Cropping Option for Uplands in Western Thailand

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In Western Thailand, maize production is mainly carried out on uplands and freshly cleared forests, which is not only reducing the forest area but also soil fertility. The fertility of land reduces over time due to many factors such as losses of fertile top soil due to lack of proper soil cover, low fertiliser inputs, intensive and inappropriate land use. We tested various maize based soil conservation options including alley cropping. A 2-year-data set with maize farmers' practice (monocropping, tillage), maize-chili-hedgerow intercropping ( $\pm$  fertilisation; minimum tillage) was used to assess the sustainability of these systems by using the Water Nutrient and Light Capture in Agroforestry Systems (WaNuLCAS) model. After calibration and validation, WaNuLCAS was used to (i) predict production sustainability of maize based agroforestry systems, (ii) improve our understanding of trees' impact on crops in alley cropping, and (iii) identify mitigation strategies for future land use. WaNuLCAS was used to run for five years continuous cropping seasons with the same practices as were used in the field experiments during 2010 and 2011. Total dry matter simulations over a period of five years showed that agroforestry systems are very sustainable production systems on uplands with only 19 % decrease as compared to farmer practice with 50 % decrease from baseline. Model evaluated options to overcome the nutrient limitation at the crop-soil-hedge interface suggested small additional amounts of fertiliser application just at crop rows planted close to hedgerows, while keeping standard amount of fertiliser in crop rows distant to the hedgerows. This helped sustaining total maize biomass yields up to  $1.8 \text{ kg m}^{-2}$ . Such strategic management options can be adopted by the local farmers' fostering soil conservation systems for sustainable agroforestry production systems in future, which will directly decrease pressure on uplands due to deforestation.

**Keywords:** Agroforestry, hedgerows, maize, Thailand, uplands, WaNuLCAS

## Simulating the Growth Dynamics of Afforestation Species under Climate Change Impacts in Northern Benin

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(Re-)Afforestation efforts, to be a sustainable solution option for combating land degradation in West Africa, have to account for projected changes in climatic conditions such as increased temperature and rainfall variability. We applied field data from an afforestation experiment in the Sudano-Sahelian zone of West Africa to agroforestry model WaNuLCAS for predicting the growth and biomass production of two woody species (*Jatropha curcas* L. and *Leucaena leucocephala* Lam.), as a first step to the assessment of the impacts of climate change on their growth. Data for model calibration and validation stemmed from the field experiment conducted over 2014 and 2015 rainy seasons and the intervening dry season. The tree species were subjected to four experimental treatments: (1) a control treatment (e.g. neither irrigation nor fertilisation), (2) irrigation, (3) fertilisation and (4) a combination of irrigation and fertilisation. The model was calibrated with the 2-year dataset from the fertilisation plus irrigation treatment and validated against the datasets from the other treatments. The seasonal dynamics of stem diameter, height, and aboveground biomass (AGB) were reasonably well reproduced by the model ( $R^2 > 0.5$ ; RMSE ca 4–50 %). The poor reproducibility of the biomass loss due to litterfall in the dry season resulted in a poor fit between observed and simulated AGB values for both species (RMSE >30 %). The overall simulation results were satisfactory, based on the values of the coefficient of determination (CD) between 1.2–4.6, model efficiency (EF) and coefficient of residual mass (CRM) which were closer to 1 and 0, respectively. These findings provide a basis for (i) predicting climate change impacts on tree growth and productivity, (ii) identifying growth-limiting factors under future climatic conditions and (iii) exploring silvicultural options for sustainable (re)afforestation efforts in the region.

**Keywords:** Climate change, land degradation, silvicultural management, WaNuLCAS model, West Africa

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## RESTORE+: A New Methodology for Addressing Landscape Restoration on Degraded Land (in Indonesia and Brazil)

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The complex interaction of ecosystem services, biodiversity, and socio-economic activities calls for a landscape approach to complement large scale conservation efforts. Such an approach requires the need to address multiple objectives in a comprehensive and integrated way in areas where pressure for high-monetary value activities are in direct competition with environmental benefits and biodiversity resources. Yet complex interactions and inclusive processes in landscape approaches make it challenging to formulate assessment mechanisms that allow for robust yet operational evaluation of projects. To address this challenge, the RESTORE+ project (R+) has developed a methodology that combines multi-objective modelling with advanced big data and citizen-sourced remote sensing analyses to obtain information on biophysical and social complexity of degraded/marginal land.

Using the R+ methodology, the project aims at providing the two focus regions, i.e. Indonesia and Brazil, with scenarios for restoration and sustainable utilisation of degraded land, and their implications on production, biodiversity, GHG emissions and social impacts (e.g. land tenure rights).

In Indonesia, IIASA's global land use model (GLOBIOM) will be adapted for the national level to analyse the dynamics of varying land use policies that include an array of degraded/marginal land utilisation scenarios. The modelling approach will be combined with participatory crowdsourced mapping campaigns, to map potential degraded/marginal land in high resolution. Utilizing crowd-empowered data gathering methods, the information that is gathered can go beyond bio-physical properties. Moreover, the restoration and utilisation cycle will look specifically into bioenergy commodities. Specific to Indonesia, various supply chain implications of varying policy scenarios to utilise degraded/marginal land for bioenergy will be analysed with

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a techno-economic engineering model (BeWhere), intended to merge the land use and energy sector perspectives for landscape energy planning.

In Brazil, the project will enhance established land monitoring and modelling capabilities and support Brazil's contribution to meeting the "Bonn Challenge". The project will identify degraded areas, assess restoration options and explore trade-offs associated with implementation of the Brazilian Forest Code.

By exploring restoration and utilisation options of tropical degraded, abandoned and/or marginal land, based on interlinked qualitative information with socio-economic and environmental parameters, the new R+ methodology will contribute to easing pressures on deforestation as well as mitigating climate change.

**Keywords:** Crowdsourcing, degradation, landscape restoration methodology, multi-objective modelling, remote sensing

## Participatory Mathematical Farm Programming - A Management Tool for Smallholders in Transition

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In the past, agricultural researchers used Mathematical Programming (MP) to analyse the multi-faceted and interlinked aspects of farm systems. However, the stage of technology and computational power limited its participatory applicability in the field. Nowadays, with new technological devices farmers can be directly involved through participatory methods as part of the research process. At the same time farmers are increasingly forced to reassess their traditional farm systems due to a combination of accelerating challenges such as climate change, emerging markets and price volatility. In this context, a tool is demanded that encompasses the traditional knowledge and experience of smallholders as well as the systematic analysis of current farming activities. We refer to this tool as Participatory Mathematical Farm Programming (PMFP), which involves farmers participation at the stage of data-collection, as well as during framing, validation and discussion of the model. Hence in this study we want to examine to which extent PMFP can be used as a management tool for smallholders in developing countries. A literature review was conducted to analyse the applicability of current participatory approaches within MP and their contributions to farm system modelling. In a second step, a farm-based mathematical micro-simulation model was built for a representative group of smallholders in San Pedro del Paraná, Paraguay. In a semi-structured household survey, data were collected on crops, livestock activities, labour and consumption behaviour. The model was calibrated and then validated by the smallholders with a Turing-Test. Finally, the general model was adapted to specific farm situations to generate possible farming strategies and was discussed with the farmers. At the end of the fieldwork, smallholders were asked to express their perceptions and suggestions regarding the PMFP-approach. The literature review showed that participation of farmers was often limited during the stage of data collection. During the application of PMFP in the field, smallholders showed interest to include it as a management tool. They highlighted comprehensibility, flexibility and applicability as the main strengths of the tool. It seems that PMFP, especially through its interactive character, was able to provide viable suggestions that farmers were willing to adopt.

**Keywords:** Farming, mathematical programming, participatory methods

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## Modelling the Opportunity Cost of Reforestation in the Upper East Region of Ghana

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Payments for environmental services (PES) have become increasingly popular tools to promote forest conservation as well as re- and afforestation including in developing countries. A common challenge in the design of PES in developing country contexts is to balance conservation and poverty alleviation goals. Addressing this challenge requires targeting strategies that integrate knowledge about farm-household characteristics and the potential for additional ecosystem service provision. In this article we test alternative approaches to predicting farm-household opportunity costs of reforestation contracts against a revealed preference benchmark derived from hypothetical auctions conducted in twelve communities, across three neighbouring districts, in the Upper East Region of Ghana with a final sample of 219 observations.

Our prediction models are based on household survey data gathered by Tambo and Wünscher (2011), and subsequent GPS-tracked measurements of the farms' plots to derive geo-spatial variables, both typically associated with opportunity costs according to theoretical and empirical literature, for example, on the sustainable livelihoods framework, and chronic poverty and remote rural areas.

A hierarchical linear model turned out to produce the best prediction of revealed preference estimates albeit at generally low levels of accuracy. Community specific effects remain one of the strongest predictors of revealed opportunity costs, suggesting that model-based targeting strategies can substantially over- and underestimate actual opportunity costs. The regression models, nonetheless, provide important insights in terms of farm-household level determinants these costs. We find, for example, that rainfall dependent farmers with a subsistence orientation and spatially scattered plots tend to have particularly high opportunity costs of joining reforestation programs.

**Keywords:** Agriculture, Ghana, hierarchical linear model, opportunity cost, payment for environmental services, reforestation, sustainable livelihoods framework

# ICRAF session

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## Oral Presentations

- NIELS THEVS, KUMARBЕК ALIEV, EVA STRENGE, MAKSAT ERAALIEV, AZIM BAIBAGYSOV, PETRA LANG, FRANK THOMAS:  
**Towards a More Water Efficient Agriculture in Central Asia through Agroforestry** 270
- RAVI PRABHU, MARK SCHAUER:  
**Can Science Lower Risks of Failure for Transformative Development Projects? The Example of Restoration and Regreening of the Sahel** 271
- KARL HUGHES, SETH MORGAN, KATHERINE BAYLIS, JUDITH ODUOL, EMILIE SMITH-DUMONT, TOR-GUNNAR VAGEN, HILDA KEGODE, MARY MUTEMI:  
**Assessing the Downstream Socioeconomic and Land Health Impacts of Agroforestry Promotion in Western Kenya** 272
- JAVED RIZVI, V. PAL SINGH, DEVASHREE NAYAK, SUNIL LONDHE, RAKESH BHUSHAN SINHA, SUROJ POKHREL, BISHWA NATH OLI, RAM HARI PANTHA, KESHAB ADHIKARI, GIASHUDDIN MIAH, TAYAN GURUNG, S.M. BOKTIAR:  
**Policy Interventions Accelerating Investment and Adoption of Agroforestry in South Asia** 273
- KEITH SHEPHERD, ERMIA S BETEMARIAM AYNEKULU, ERICK TOWETT, MARKUS G. WALSH:  
**A New Paradigm for Evidence-Based Land and Soil Management Recommendations** 274
- CORY WHITNEY, DENIS LANZANOVA, KEITH SHEPHERD, EIKE LUEDELING:  
**Nutritional Impacts of Transitioning from Homegardens to Industrial Farms in Uganda** 275

## Posters

- DEVASHREE NAYAK, V. PAL SINGH, JAVED RIZVI, JAGDEESH RAO PUPPALA, LOUIS VERCHOT:  
**Rehabilitation of Degraded Lands through Agroforestry Systems at Rajasthan and Odisha, India** 276
- NIELS THEVS, KUMARBЕК ALIEV:  
**77 Million Trees for Kyrgyzstan** 277

- RODRIGO CIANNELLA, RAVI PRABHU:  
**Sustainable Bioenergy Production through Agroforestry Systems in India, Brazil and Kenya** 278
- JAMES ROSHETKO, GERHARD MANURUNG:  
**Smallholder Teak Production Systems in Gunungkidul, Indonesia** 279
- NGUYEN LA:  
**Agroforestry for Livelihoods of Smallholder Farmers in North-west Vietnam – Research in Development** 280
- ELOK MULYOUTAMI, JAMES ROSHETKO, ENDRI MARTINI, JANUDIANTO:  
**Gender, Species Priorities, and Domestication in South and Southeast Sulawesi, Indonesia** 281
- ENDRI MARTINI, JAMES ROSHETKO:  
**Agroforestry Farmer Field Schools: Informed Farmers for Sustainable Landscapes** 282
- AULIA PERDANA:  
**Strategy for Value Creation: Commodity Value Chains in Sulawesi, Indonesia** 283
- ATIEK WIDAYATI, NI'MATUL KHASANAH, PANDAM PRASETYO, JHON R. SIRAIT, SRI DEWI BIAHIMO, CHANDRA I. WIJAYA, ELISSA DWIYANTI, SONYA DEWI, JAMES ROSHETKO:  
**Landscape Management Strategies for Rural Livelihoods and Ecosystem Service Protection in Sulawesi, Indonesia** 284
- OGOSSY GASAYA SERERYA, ANTHONY KIMARO, LEOPOLD LUSAMBO, GÖTZ UCKERT, JOHANNES HAFNER, STEFAN SIEBER, FRIEDER GRAEF:  
**Integrated Food and Biomass Production Systems for Enhanced Food Security and Environmental Sustainability in Tanzania** 285
- ALICE MUCHUGI, JIANCHU XU, AGNES GACHUIRI, JACINTA KIMITI, GACHERI MURIIRA, FESTUS MUTISO:  
***Calotropis procera*: A New Investment for African Drylands** 286
- MUHAMMAD MEHMOOD-UL-HASSAN:  
**EU-World Agroforestry Center Collaboration for Developing R&D Capacity in Agroforestry: Key Highlights from 2011–2016** 287
- NEGUSSE YIGZAW, CORY WHITNEY, CHRIS-ACKELLO OGUTU, JOHN MBURU, EIKE LUEDELING:  
**Viability of an Irrigation Development Intervention in Tigray: An Application of Stochastic Impact Evaluation** 288

ISSOUFOU LIMAN, CORY WHITNEY, JAMES KUNGU, EIKE LUEDELING: <b>Modelling Risk and Uncertainty in Flood-Based Farming Systems in East Africa</b>	289
HAIFA BENMOUSSA, MOHAMED GHRAB, MEHDI BEN MIMOUN, EIKE LUEDELING: <b>Tunisia's Temperate Fruits and Nuts Are Threatened by Climate Change</b>	290

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## Towards a More Water Efficient Agriculture in Central Asia through Agroforestry

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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, water consumption of the trees that form shelterbelts is unknown.

In order to understand the water consumption and water productivity of a shelterbelt agroforestry system versus a corresponding non agroforestry system, tree water consumption and micro climate were assessed during the growing season 2016 on two representative sites in Chui Valley, Kyrgyzstan and Kazakhstan. Tree water consumption was assessed through sapflow measurements. Micro climate data were used in order to calculate crop evapotranspiration. The measurements of tree evapotranspiration together with measurements of crop evapotranspiration allowed compare the overall evapotranspiration of a shelterbelt system with a non-shelterbelts system. Data on crop yield losses and benefits from shelterbelt trees were collected through farm interviews.

Results indicate that wind speed is significantly reduced inside the two shelterbelt systems. As wind speed is a major driver of crop evapotranspiration, crop evapotranspiration inside shelterbelt is reduced compared to outside the shelterbelt systems. The overall water consumption of shelterbelt system was found to be lower by 10 % compared to non-shelterbelt systems. Income from shelterbelt trees overcompensated crop yield losses.

**Keywords:** Elm, Penman-Monteith, poplar, sapflow, shelterbelt, water productivity, wind break

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## Can Science Lower Risks of Failure for Transformative Development Projects? The Example of Restoration and Regreening of the Sahel

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An estimated 83 % of sub-Saharan Africans are dependent on the land for their livelihoods, yet two-thirds of African land is already degraded to some degree. In many African countries, more than 65 % of the land area is degraded. By eroding the productivity of farming systems, land degradation reduces incomes and food security. By reducing the resilience of the ecosystems populations depend on, land degradation worsens their exposure to the vagaries of the increasingly erratic weather of the Anthropocene. Migration is thus, unsurprisingly, accelerating with about 60 million people at risk of being uprooted by desertification and land degradation in the next few decades in sub-Saharan Africa. Can the science of agroforestry, land health assessments and the economics of land degradation be integrated into development projects so that they can lower their risks of failure? The presentation explores the joint experiences and plans of the World Agroforestry Centre (ICRAF) and GIZ as they seek to answer this question while improving the livelihoods of 500,000 small-holder farmers in eight countries in the Sahel as 1 million ha of their degraded farm land is 'regreened'. Taking a 'research in development' approach that seeks to integrate evidence into decision making on policies and investments by a range of stakeholders and partners, the project focuses on the potential of agroforestry and especially Farmer Managed Natural Regeneration and our understanding of the processes of land degradation and rehabilitation to act as the vehicles for transformative change. The presentation will discuss collaborative, institutional and technical arrangements in this structured 'learning for development' project supported by the European Commission.

**Keywords:** Africa, agroforestry, economics, investment, land degradation, resilience, restoration, rural development, small holder farmers



## Assessing the Downstream Socioeconomic and Land Health Impacts of Agroforestry Promotion in Western Kenya

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Agroforestry is widely purported to improve the livelihoods of smallholder farmers, rehabilitate degraded landscapes, and enhance the provisioning of critical ecosystem services, including carbon sequestration. Yet, the evidence base supporting these longer-term impacts is weak. Using a quasi-experimental evaluation design based on a theory-based and mixed methods framework, our study investigates both the downstream and intermediate effects of an eight year effort led by Vi Agroforestry (herein Vi), a Swedish non-governmental organisation (NGO), to promote agroforestry in large sections of Bungoma and Kakamega counties in western Kenya. In particular, we compare two sets of households against various outcome measures along the causal chain: those belonging to (a) 226 pre-existing farmer groups operating in 60 targeted programme villages; and (b) 206 non-targeted pre-existing farmer groups operating in 61 geospatially and demographically matched comparison villages. To further counter selection bias, we combine several econometric analytical methods, including two-stage least squares regression (2SLS), with difference-in-differences estimation. In addition, to triangulate key findings and interrogate impact pathways, unforeseen outcomes, and unexpected quantitative results, we carried out semi-structured in-depth interviews with a sub-sample of 40 purposively selected programme participants. We also applied process tracing to investigate the linkages between Vi's programme and previous agroforestry research carried out by the World Agroforestry Centre (ICRAF). We find these research-to-programme linkages to be strong and that a significantly greater – albeit geographically variable – uptake of the agroforestry practices promoted by Vi took place in the villages it targeted. Significant, yet modest and variable effects, were also identified for tree product income, fuelwood access, and milk yields among dairy farmers. Ironically, soil organic carbon (estimated via remote sensing) increased at a higher rate in the sampled farm plot's in the programme villages, overall, but so too did soil erosion. Finally, while we find limited evidence that the programme significantly bolstered food security, resilience, and education progression and spending, statistically significant, albeit modest, effects we identified for our asset and consumption expenditure measures (which includes the study's primary outcome variable), particularly among female farmer group members.

**Keywords:** Agroforestry, asset accumulation, causal chain, consumption expenditure, impact, mixed methods, process tracing, quasi-experimental, research impact, soil erosion, soil organic carbon, theory based impact evaluation, Vi Agroforestry

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## Policy Interventions Accelerating Investment and Adoption of Agroforestry in South Asia

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In 2014 India approved a national agroforestry policy to resolve the bottlenecks like prohibition of felling and transport of tree (agroforestry) species. In its third year of implementation, the policy has been effective in freeing a good number of farm-grown tree species from felling and transit regulations in many of the Indian states, in upgrading a national research centre on agroforestry, and establishing a National Sub-Mission on Agroforestry to promote agroforestry. ICRAF contributes to the technical group which supports the implementation of the newly created mission. In this short period, policy has been instrumental in channelizing large investments. For 2016–2020, through the newly created agroforestry mission, India has committed about \$ 410 million, and India's finance commission has invested an additional \$ 9.0 billion to encourage states increasing their green cover. India identified agroforestry as the major tool to fulfil its INDC commitment, and State Governments are investing in agroforestry for increased mitigation, adaptation, and resilience to climate change. Sixty per cent of timber requirement of India is sourced through agroforestry, and timber to the value of \$ 8 billion year<sup>1</sup> is still imported which is about 20 % of the total requirement of the country.

Success of agroforestry policy in India is causing a ripple effect. Through a National Consultation held in Nepal, stakeholders' identified the need to develop a national agroforestry policy for Nepal. Recommendations of the consultation were jointly issued by the Ministries of Agriculture and Forest of Nepal as "Kathmandu Declaration on Agroforestry". As a follow up, ICRAF with funding from the Climate Technology Centre and Network (CTCN) works with Nepal to develop its policy. Other South Asia countries through South Asia Association for Regional Cooperation (SAARC) have expressed deep interest to work with ICRAF either on policy/ advocacy related issues, or to implement a regional agroforestry programme in eight member countries: Afghanistan, Bangladesh, Bhutan, India, Pakistan, Maldives, Nepal, and Sri Lanka. Bangladesh in collaboration with ICRAF, has initiated developing its own agroforestry policy.

This paper will discuss in details how the Indian policy is enhancing adoption of agroforestry not only in India, but creating a ripple effect in the region as well.

**Keywords:** Agroforestry, India, Nepal, policies, ripple effect

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## A New Paradigm for Evidence-Based Land and Soil Management Recommendations

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There has been a failure in developing evidence-based land, soil and crop management recommendations due to two fundamental limitations. The first limitation is that target areas have not been defined and properly sampled when setting up experiments or observations, which has prevented sound inference of results to the area of interest. The second limitation is that uncertainty in the evidence used to make the recommendations has been ignored, thereby pushing the decision risk on to the farmer or land user, and robbing the researchers of the knowledge required on how to reduce uncertainty and improve recommendations. Currently, the data used to develop recommendations are rarely traceable. Recommendations are rarely validated in a systematic way.

A surveillance framework for making evidence-based land, soil and agronomic recommendations is presented and illustrated with an example of developing fertiliser recommendations in the Africa Soil Information Service (AfSIS). The cropland areas of a country are first identified as the region of interest. A statistically valid sampling scheme is used for siting soil sampling campaigns and agronomic trials. Low cost and rapid spectral measurement methods are used to handle the large numbers of sample analyses required. The approach permits unbiased estimates of soil constraints and crop responses to be made and mapped with the aid of remote sensing covariates. Uncertainty in recommendations is presented to end users and value-of-information analysis used to pinpoint where further information is required to improve recommendations and reduce end-user decision uncertainty. Iterative Bayesian updating is used to systematically improve recommendations over time.

**Keywords:** Bayesian, inference, land, recommendations, soil

## Nutritional Impacts of Transitioning from Homegardens to Industrial Farms in Uganda

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Uganda's agriculture is currently confronted with a major government decision, set to transform the country's farming landscape. The national development plan (Vision 2040) calls for a transition from small-scale farming, which currently supports the majority of Ugandans, to large-scale commercial agriculture. While this plan is likely to boost staple crop production, its impacts on human nutrition have not been adequately explored. Given its multifaceted and complex nature, an *ex-ante* evaluation of Vision 2040 requires the integration of knowledge and systems thinking from beyond the discipline-specific approaches that are often used. To this end, decision analysis, a decision-support approach from the private sector, offers tools for including 'intangible' factors that are important for the decision but difficult to measure. We applied Bayesian Networks (BN), a probabilistic causal modelling technique, for decision analysis concerning Vision 2040's impact on the nutritional situation of Ugandans. To project future supply of micro and macronutrients, we convened a team consisting of technical experts and potentially affected stakeholders to construct a BN impact model. We used various group-work techniques to produce a consensus model that included the perspectives of all participants. To structure the analysis, participants identified five decision-relevant questions, relating to (1) dietary diversity, (2) human displacement, (3) expected changes in urban and rural diets, (4) future income prospects for displaced farmers and (5) changes in crop diversity. For each question, team members designed graphical models that were then reconciled into one comprehensive model projecting the nutritional impacts of Vision 2040. The model was converted into a BN, which was parameterised with probability distributions elicited from participants. To ensure accuracy in this step, participants were trained in techniques aimed at reducing estimation bias (e.g. overconfidence). Results indicated little change in terms of macronutrient deficiency (Hunger) but a worrying increase in micronutrient deficiency (Hidden Hunger) with the implementation of Vision 2040. The BN approach proved effective in generating a comprehensive working model of the implications of 'Vision 2040' for the nutritional status of households in Uganda. Such methodologies and model outputs hold promise for helping decision makers gain insight into the important linkages between nutrition and policy.

**Keywords:** Bayesian networks, decision analysis, East Africa, food security

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## Rehabilitation of Degraded Lands through Agroforestry Systems at Rajasthan and Odisha, India

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Land degradation is a complex and continuously occurring phenomenon caused both by nature and human actions. Land degradation is a threat to sustainable livelihoods globally and spreads across all major ecologies. This study reports data from assessment of rehabilitation work done, a decade ago, in a region with semi-arid ecology in Rajasthan and in a sub-humid area in Odisha, India. It presents lessons learnt on the extent, to which degraded lands can be rehabilitated through agroforestry interventions.

A decade ago, rehabilitation interventions were carried out at three degraded areas in Rajasthan and two in Odisha. These interventions mainly included, 1) biological - assisted regeneration of natural vegetation and seeding with local tree and fodder species, 2) social - fencing to protect vegetation from grazing, and limiting the biomass harvesting, and 3) physical - making small check dams and anicuts, etc. The fields where no interventions were carried out (control) were compared with the rehabilitated fields through the Before and After in Control and Impacted (rehabilitated) Plot (BACIP) model with measurements on soil physical, chemical and hydrological properties, and vegetation.

Most land in the study areas were severely degraded and had very low biodiversity, vegetation cover, soil fertility and productivity. After a decade of rehabilitation interventions, the soil properties in general exhibited only small changes, but interventions led to a clearly noticeable improvement in vegetation cover, both in species diversity and biomass, and in hydrological parameters. The rehabilitated fields had mixed vegetation; trees, shrubs and grasses, whereas the control fields featured mostly scrubby vegetation and grasses. These results point out the high potential of agroforestry systems for bringing degraded lands into productive and economic use.

**Keywords:** Agroforestry, degraded lands, rehabilitation, soil properties

## 77 Million Trees for Kyrgyzstan

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Forest area in Kyrgyzstan in the 1980s was 1.5 million ha, now it is only 1.1 million ha, i.e. 5.5% of the total country area. Still, about one third of the population uses forests as source for wood or grazing land. Annual timber and fuel wood demand are estimated with 160 000 to 500 000 m<sup>3</sup> and 2 million m<sup>3</sup>, respectively. 25 000 to 45 000 m<sup>3</sup> are supplied by the State Forestry Fund. The remaining wood is imported from Russia or cut illegally.

Agroforestry helps to increase the number of trees in the landscape where people live and need wood or other tree products. So people have less demand to use wood from forests and forest degradation can be avoided. Tree shelterbelts are a major agroforestry system all over Central Asia with Poplars as main species. After collapse of Soviet Union, large numbers of shelterbelt trees were cut.

For this study we assumed to lay shelterbelt grids of 1000 × 1000 m, 500 × 500 m, and 250 × 250 m hypothetically over all crop land of Kyrgyzstan. The 1000 × 1000 m grid would yield 400,000 m<sup>3</sup> timber per year and therefore could already meet most of the annual timber demand. The 500 × 500 m grid would result in 77 million trees with a total timber volume of 11.1 million m<sup>3</sup>. The 250 × 250 m grid could meet annual timber and fuel wood demand.

Poplars are planted by the private sector without donor money, partly in shelterbelt like arrangements, as plantations. Rules and laws are unclear regarding agroforestry, which is the major obstacle for a further expansion of these systems.

**Keywords:** Agroforestry, Central Asia, forest degradation, GIS analysis, tree shelterbelt, wood supply

## Sustainable Bioenergy Production through Agroforestry Systems in India, Brazil and Kenya

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Poor rural and urban people in developing countries need access to energy to fuel their livelihoods. Energy is required not only for basic household use, but also for water pumping, land preparation, post-harvest management, processing, packaging, transportation and many other activities. Bioenergy production through sustainable practices and integrated approaches, such as agroforestry systems, can contribute not only to improving energy access, but also to several other social and environmental benefits.

Between 2013 and early 2017, the Programme for the Development of Alternative Biofuel Crops tested the hypothesis that biofuels can be sustainably produced, improve livelihoods and contribute to rural development. The initiative was implemented by the World Agroforestry Centre (ICRAF) in partnership with centres of excellence and other stakeholders, including from governments, private sector and civil society. Pilots were established in three main target countries: India, Brazil and Kenya. Pursuing a landscape approach, the Programme developed and/or assessed sustainability aspects of agroforestry-based integrated food-energy systems that provide multiple benefits. These include several bioenergy products (e.g. straight vegetable oil, biodiesel, biogas, briquettes) and valuable co-products (e.g. animal feed, organic fertilisers, biopesticides, biochar) that can provide local clean energy solutions, while boosting food production and incomes. Furthermore, such products were obtained from perennial species (mostly trees with oil-bearing seeds) that often grow on marginal and degraded lands, such as pongamia (*Millettia pinnata*), simarouba (*Simarouba glauca*), mahua (*Madhuca longifolia*), neem (*Azadirachta indica*), calophyllum (*Calophyllum inophyllum*), macaúba (*Acrocomia aculeata*) and croton (*Croton megalocarpus*), inter alia.

Results demonstrated the production of biofuels (and other bioenergy products) from native oilseed trees within agroforestry systems is not only economically viable, but also has a positive social and environmental impact greater than traditional models based on monoculture of annual (and often food) crops. The Programme contributed to reduce energy poverty, increase household income, improve agricultural productivity, strengthen food security and enhance resilience of smallholder farmers, through diversification of production and linkages to innovative value chains – and all this while sequestering carbon and restoring degraded soils.

**Keywords:** Biofuel, calophyllum, croton, macaúba, mahua, neem, pongamia

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## Smallholder Teak Production Systems in Gunungkidul, Indonesia

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Teak (*Tectona grandis*) is produced in industrial plantations in more than 43 countries. National and international demand for teak timber exceeds the sustainable yield from natural forests and plantations. High demand creates opportunities for enterprising farmers. Teak is now grown in smallholder agroforestry systems in many tropical countries. These systems enable farmers to diversify production, reduce farm risk, contribute to food security, and generate much needed income. They also meet commercial needs for timber and improve environmental conditions. This paper reports the contributions of teak systems to smallholder livelihoods in Indonesia, where farmers have been producing teak for over 50 years. Indonesian farmers in Gunung Kidul cultivate teak as one component in integrated multispecies agroforestry systems. Teak accounts for 56 % of the trees in these systems. Annual cropping is an important aspect of these systems, producing commodities for both household consumption and market sale. Besides supplying food for households, smallholder teak systems provide 40 % of household income from agricultural and timber crops. Teak and other tree crops allow households to re-allocate labour to off-farm employment when those opportunities are lucrative. However, farmers suffer from limited resources, labour and access to information, which constrain the productivity of their teak systems. Specific recommendations are provided regarding how smallholders can adopt improved silvicultural and marketing management. Roles for government, support agencies and industry are outlined that would provide benefits to all parties. Policy changes are identified that would motivate smallholders to improve the management of their teak systems. Conclusions and recommendations are applicable to smallholder teak systems across the tropics.

**Keywords:** Agroforestry, diversification, livelihood, smallholder, teak, timber



## **Agroforestry for Livelihoods of Smallholder Farmers in Northwest Vietnam – Research in Development**

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In Northwest Vietnam, rain-fed crop cultivation is dominated by monoculture maize, upland rice and cassava on sloping lands. The loss of topsoil during the rainy season leads to a depletion of soil fertility and plant nutrients leading to reduction in crop yield. Farmers have to invest heavily in chemical fertilisers for the maize to remain productive compared to the past. Harsh weather conditions also reduce yields or even lead to crop loss and make soil and water conservation more difficult.

The project has introduced trees in mono-cropped landscapes through agroforestry to reduce dependence on annual crops, as well as increase and diversifies incomes from tree products, while also conserving the natural resource base. The research approach combined different activities, which support each other to be possible bring valuable research results to apply to reality. The agroforestry systems were designed through participatory which the scientific knowledge and local knowledge are combined. These established trials are evaluated to find out the suitable options. The add value for agroforestry adoption also involved research on propagation of priority agroforestry species, small-scale nursery development, research and transfer processing techniques, exploring value-adding opportunities by smallholders and facilitating links between producers and other market actors. The research findings were spread through farm cross-visits, farmer field days and training sessions held at the test sites, accompanied by regular impact assessments. In addition, these findings were used to inform the communication strategies, policy dialogues, extension and expansion activities through workshops, media products, extension materials and training. To promote the agroforestry adoption, the project has been developed at three levels: Participatory Farmer Trials, Farmer Demonstration Trials and Exemplar Landscapes where the scientific knowledge and local knowledge are combined and utilised. This approach is primarily based on the classic extension and dissemination theories, but highlights the important elements of collective action and social capital development among farmers, and between extension workers, local governments and researchers. The results have been found useful in demonstrating farmer adoption of agroforestry practices and developing value chains and market linkages in varying contexts, and they support the local governments to define strategy development through policy interventions.

**Keywords:** Agroforestry, livelihoods, local knowledge, smallholder farmers

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## Gender, Species Priorities, and Domestication in South and Southeast Sulawesi, Indonesia

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Women and men have different sets of knowledge, experiences, and strategies in addressing aspects of plant domestication such as plant propagation, management, utilisation and marketing. Identification of gender roles and knowledge related to tree domestication is important in planning for tree-based livelihood enhancement and sustainable environmental management, however, such identification has not yet been sufficiently researched to date. Thus, this study investigated gendered selection of economically priority species and their domestication in South and Southeast Sulawesi. With using ranking through pebble game as a method, we identify the top five priority species, along with domestication preferences and division labour by gender. Focus group discussions (FGDs) were held with 300 community members (45 % women) of 19 villages in 4 districts in South and Southeast Sulawesi province Indonesia. Men and women were disaggregated into different FGD groups. The study showed that both men and women give priority to tree species with high economic value; the management of those species is a stronger priority for men but is also expressed by women. However, specifically for their livelihoods, women are keen to domesticate vegetables and other annual crops that contribute directly to household food security and nutrition. Women focus their domestication activities on land near the home. Timber, as in many areas, were the domain of men. Women's contribution to timber domestication was lower than the engagement of men due to the lower interest/priority of women. Women's role in seed selection and propagation is crucial for agroforest development and biodiversity conservation. Their knowledge and skills, developed through the tasks they perform, are important aspects for agroforest management.

**Keywords:** Gender role, household decision making, tree domestication, tree prioritisation, women

## **Agroforestry Farmer Field Schools: Informed Farmers for Sustainable Landscapes**

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Most of agroforestry extension methods are modified from methods developed for agricultural extension. These extension methods were mainly developed to enhance production of staple crops or short term crops with production cycles of less than one year especially in monoculture systems. The presences of perennial crops in agroforestry systems require more than 1 year to see the results of agroforestry extension programs. Also, the focus of agroforestry extension programs is not only focused on one commodity but tries to optimise production of different crops under one agroforestry system. Thus, agroforestry extension need to focus more on 'equipping' farmers with knowledge that can enhance their analytical skills in managing their agroforestry farms. Farmer field school (FFS) is one of the extension methods that facilitate the process of knowledge transfer. A two-way communication between farmers and extension agents in FFS facilitates the interactive learning process that enhances farmers' willingness to test technologies introduced through the extension program. Designing an Agroforestry Farmer Field School (AFFS) focusing on agroforestry farm management is expected to enhance agroforestry farm productivity. The objectives of the AFFS are to: 1) enhance farmers' analytical skills in managing agroforestry that support the sustainable landscape management; 2) provide innovative extension approach that enhance farmers' analytical skills and information networking; 3) utilize farmer demonstration trials and nursery as places to test and learn new agroforestry technologies; and 4) prepare expert farmers who will play a role as agroforestry extension agents. Topics learned in the AFFS are linked to sustainable landscape management with a broad spectrum from germplasm improvement to garden management. Combinations of different extension methods are used in the AFFS, ranging from scientist-to-farmer, farmer-to-farmer, field site visits and development of demonstration trials. The AFFS on agroforestry farm management was tested in Sulawesi, Indonesia under Agroforestry and Forestry project (AgFor) from 2013 to 2015. The implementation of AFFS has contributed to the enhancement of agroforestry as an important source of livelihood in sustainable landscapes of Sulawesi.

**Keywords:** AgFor, agroforestry extension, demonstration trials, expert farmer, Sulawesi

## Strategy for Value Creation: Commodity Value Chains in Sulawesi, Indonesia

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In contrast with the rich biodiversity, the strong focus on single commodity in Sulawesi, such as maize, is leading to ‘boom or bust’ cycles where downturns occur after periods of rapid growth. These cycles exacerbates the condition of most of the rural communities who subsist at low economic levels. Based on a case study in South and Southeast Sulawesi, smallholders managing their own non-timber products typically lack access and knowledge on good seeds and its source, lack information on good agriculture practices, lack knowledge and access of input and supplies, lack of post-harvest handling skill, lack of quality knowledge and price. Smallholders basically lack established marketing strategies and are unaware of the underlying competition. This study investigates the lesser-explored smallholders’ non-timber products to provide better understanding on how smallholders and other value chain actors at smallholder level develop strategies for value creation. Results from the study found some obstacles, but there are opportunities for smallholders to access more lucrative value chains by increasing their awareness of market chains and market specifications, engaging in post-harvest processing to increase the value of the commodity, and expanding their role in the value chain. However, smallholders showed low sense of value creation by not understanding what traders and consumers really need, and mostly selling what is produced instead of producing what sells. To fully engage in market opportunities it is imperative for smallholders to understand their target market and develop active marketing strategies. Key factors to address include improving smallholders’ crop management to produce products with higher potential value, the barriers faced by new market participants, the bargaining power of buyers (i.e. traders or collectors), possible substitutes to products in related industry, and competition among smallholder producers.

**Keywords:** Market, non-timber products, smallholder, Sulawesi

## **Landscape Management Strategies for Rural Livelihoods and Ecosystem Service Protection in Sulawesi, Indonesia**

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Reconciliation between community livelihoods and sustainable natural resource utilisation is urgent. Recent approach embraced ecosystem service principles, where the connection between the needs for conservation and the livelihoods importance is established via the functions of the ecosystems to the human needs. Ecosystem services are managed in a landscape context where socio-economic-cultural conditions of the actors are involved. We exercised an approach that covered diagnostic steps up to multistakeholder forum to develop landscape management strategies that formed the basis for the formulation of government regulations and government-community agreements for collaborative management. The approach was applied in seven landscapes in three provinces (South Sulawesi, Southeast Sulawesi, Gorontalo) in Sulawesi Island, Indonesia. In some instances, the landscape has been well maintained with agroforestry practices, while in other instances, natural resource degradation largely occurs reflecting complex interactions with the utilisation for local livelihoods. The domain of the strategies developed encompass: 1) Rewards for source water provision through downstream-upstream governance, 2) Collaborative land rehabilitation for degraded areas and 3) Community management rights at forest with conservation status. Experience from the processes were observed and assessed to derive lessons learnt based on the five capitals of the sustainable livelihoods framework. From the case studies, it is concluded that issues of ecosystem services versus livelihoods need to be addressed at landscape level since there are interactions in spatial context, across time and across actors. Multi-stakeholder participation needs to be incorporated as early as possible in order to create ownership and continued commitments post strategy development. The biggest challenge during the process represents the social capital, while to some extent challenges also cover human and financial capitals.

**Keywords:** Agroforestry, ecosystem services, landscape approach, Sulawesi, sustainable livelihoods

## Integrated Food and Biomass Production Systems for Enhanced Food Security and Environmental Sustainability in Tanzania

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Land degradation, reflected in soil fertility depletion and declined vegetation cover, is still a major biophysical constraint to sustained agricultural productivity in sub-Saharan Africa (SSA). This problem is aggravated further by high rate of wood extraction for woodfuel (firewood and charcoal) supply, which accounts for 27 % of deforestation in Tanzania. Technologies integrating crops and biomass production with efficient use of woodfuel are critical for intensifying agriculture in SSA to enhance food security and minimise land degradation. Limited information on the socio-economic benefits of this integrated approach affects adoption. We evaluated socio-economic and health benefits of integrating agroforestry and improved cooking stove (ICS) technologies to sustain maize and fuelwood supply in Dodoma, Tanzania. Household fuelwood consumption and socio-economic benefits from improved cooking stove adaptors were determined using the controlled cooking test (CCT) and questionnaire survey. Gas and particulate matter (PM<sub>10</sub>) emissions were determined using gas analyser and particulate matter sampler, respectively. Three stone fire stove (3STF) was used as a reference for the CCT. Allometric equations were developed to assess wood biomass of trees in shelterbelts, woodlot, *Gliricidia*-maize intercropping, on contours and farm boundaries. The CCT revealed that, ICS save 50 % of firewood and 40 % of cooking time, leading to 50 % reduction in the firewood budget per meal compared to 3STF. Accordingly, annual firewood consumption and collection time in household adopting ICS were reduced by 67 % and 50 %, respectively. Similar results (56 – 65 % reduction) were also noted for emissions of PM<sub>10</sub> and gases (CO, SO<sub>x</sub>, NO, and NO<sub>x</sub> in mg/nm<sup>3</sup>). Tested agroforestry practices produced 0.5 – 8 t ha<sup>-1</sup> of wood, which was sufficient to satisfy a 5-member household for 11 and 34 months when using traditional 3STF and ICS respectively. The reduction of firewood budget, time for cooking and fuelwood collection and gas emission reflect economic, health and environmental benefits of ICS technologies. Additional benefits were noted when ICS was linked to on-farm wood production. Apparently on-farm wood supply holds high promise to meet household cooking energy demand when combined with ICS. Besides firewood, *Gliricidia* intercropping produced maize grain yield (1.2 t ha<sup>-1</sup> – 3.2 t ha<sup>-1</sup>), signifying contributions of this integrated approach to sustain food production.

**Keywords:** Agroforestry, controlled cooking test, GHG emissions, improved cooking stoves, semiarid zones

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## ***Calotropis procera*: A New Investment for African Drylands**

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*Calotropis procera*, commonly known as milkweed, is an evergreen dry land shrub native to tropical Africa. In some of the dry parts of the Sahel, it is sometimes the only green plant in sight. The local communities have limited use for the species except for some traditional medicine applications and cheese making. However, the potential of using the fibre from mature fruits has aroused interest on the species. Preliminary analysis have shown that the fibre has good quality for the textile industry comparable to silk. For a sustainable *C. procera* based fibre industry, there is need to “domesticate” the species to ensure optimal quality and quantities. As a cultivated plant, the species will offer hope of growing a cash crop in regions with minimal where no other cash crop survives. In addition, its leaves have shown good potential for use as high quality livestock fodder. Communities in the semi-arid and arid areas of sub-Saharan Africa are adversely being affected by the impact of climate change; with reduced annual rainfall, few crops that used to grow in the region can no longer grow to maturity due to the prolonged. Interestingly, *C. procera* still thrives in these drylands showing its resilience to this extreme conditions. It will therefore offer hope to improve livelihood for the resource poor farmers as well as reduce environmental degradation as a ground cover. ICRAF is leading the species domestication project in Kenya with partners in China assessing the fibre quality for textile industry. Preliminary findings towards the domestication of *C. procera* are presented here.

**Keywords:** *Calotropis procera*, domestication, fiber, fodder, sub-Saharan Africa, textile industry

## EU-World Agroforestry Center Collaboration for Developing R&D Capacity in Agroforestry: Key Highlights from 2011–2016

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Since its foundation in the 1970's, agroforestry science has evolved from defining key concepts, approaches and flagship technologies towards its increasing contribution to ecologically sound land use, food security and income generation in the global North and South. With the launch of Sustainable Development Goals in Paris in 2015, most agriculture related efforts to adapt to and mitigate the effects of changing climate in developing countries call for moving away from “monoculturation” of agricultural landscapes towards “integration” through agroforestry systems at various scales where crops, trees and livestock enterprises are integrated to provide economic, social and ecological resilience, as well as opportunities for reversing land degradation for smallholder and family farms. To make such integration possible, the need for research-based agroforestry solutions at farm, landscape and national scales is thus ever more urgent.

Capacity development in agroforestry, like many other fields, can take place in multiple ways. Education and training (formal and informal, basic and higher), internship opportunities, study visits, advisory and extension services, partnerships, knowledge networks and leadership development for individuals and organisations are some of the ways in which capacity gets developed. The aim of all such efforts is to effect changes in knowledge, behaviours and attitudes. All capacity development efforts are aimed at fostering innovation, discovery and delivery at individual, organisational and system levels.

The aim of this paper is to summarise the highlights of capacity development efforts between the European Union and the World Agroforestry Center towards developing capacities, particularly for research in and for development across various continents. Key areas for further deepening such collaboration are also identified.

**Keywords:** Agroforestry, capacity development, European Union, World Agroforestry Center



## Viability of an Irrigation Development Intervention in Tigray: An Application of Stochastic Impact Evaluation

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Irrigation dams and other forms of flood and rainwater harvesting infrastructure may make important contributions to help farmers reduce poverty, improve food and nutrition security, and adapt to the impacts of climate change. Water harvesting and retention systems are of particular importance in arid and semi-arid areas, such as northern Ethiopia, where rain fed agricultural production faces severe drought risks. Dam construction incurs high costs, however, and governments or other investors are often unsure of whether such investments are justified. Assessing the feasibility of water harvesting infrastructure investments and optimising expected returns from them requires detailed *ex ante* appraisal. Due to the inherently complex and uncertain consequences of agricultural investments and often severe data scarcity, traditional cost-benefit assessment methods face limitations. Stochastic Impact Evaluation (SIE) attempts to overcome the particular challenges of evaluating investments in such contexts. Here we assess the viability of an irrigation dam intervention in Raya valley, Ethiopia. To achieve this, we worked with stakeholders to generate a causal model of the planned intervention's impact pathway. We then applied an SIE approach based on integration of Monte Carlo simulation, Partial Least Squares regression, and Value of Information analysis. The model was developed and estimates for the input variables were collected from ten subject matter experts via expert data elicitation methods. Preliminary results indicate that the effect of the proposed dam project varies for the different stakeholders involved. Further analysis is underway to identify the variables with high information value and whose measurement could best inform the investment decision. If further information is needed in order to decide on a preferable course of action, decision makers should target these variables for measurement. Our results demonstrate that SIE is an effective approach for providing guidance to decision-makers in agricultural development, in the face of system complexity and uncertainty.

**Keywords:** Dam construction, investment viability, irrigation, probabilistic simulation, stochastic impact evaluation

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## Modelling Risk and Uncertainty in Flood-Based Farming Systems in East Africa

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Flood-based farming systems (FBFS) rely on seasonal floods that provide beneficial water and nutrients, but also pose many risks and uncertainties for agricultural production. FBFS are extensive in East Africa, particularly in Kenya and Ethiopia, where they provide food to millions of people, along with many other agro-ecosystems services. Scientists have developed many crop models as important tools for agricultural development, but existing models are difficult to use in FBFS settings, due to the particular water supply characteristics of such systems. Development of new models that produce reliable results in FBFS settings has proven difficult due to system complexity, site-specific differences among different FBFS and lack of adequate datasets to develop and parameterise models. This difficulty is further exacerbated by socio-economic and management aspects that are crucial for system functioning. FBFS models must consider sediment management, infrastructure for water acquisition and social rules for water sharing among FBFS users.

Bayesian Networks (BN) are useful tools for analysing complex systems. They can be used for creating expert-informed probabilistic models that can help overcome the lack of information that is common in agricultural systems such as FBFS. In order to apply a BN informed by available sources of information on FBFS in Kenya and Ethiopia, we held knowledge gathering group discussions with farmers, academics, and practitioners at Mekelle University and Alamata town in Ethiopia, and Kisumu County in Kenya in 2016. Experts were asked to start with a high level discussion to frame the overall BN and identify important influencing factors in FBFS. Thereafter, the participants were engaged in model development to produce graphical models that represented all important relationships. Probability distributions were then estimated using experts' knowledge together with many other sources of information, including the FBFS literature. Initial results indicate the volatility and the maintenance of the flooding system as important factors determining the performance of FBFS of the region.

**Keywords:** Bayesian networks, crop model, East Africa, flood-based farming systems

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## Tunisia's Temperate Fruits and Nuts Are Threatened by Climate Change

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Fruit and nut orchards make up more than 20 % of Tunisia's agricultural area. Many species grown in these orchards, such as pistachios, almonds and peaches, fall dormant during the cold season and require low winter temperatures to resume growth in spring. Tunisia is one of the world's warmest regions where such species are commercially grown. It is therefore likely that these orchards are at high risk from climate change. Tree phenology, the timing of annual life cycle events, has been identified as a sensitive indicator of climate change, and it carries valuable information on the ability of tree species and cultivars to remain viable under changing climate conditions.

To explore past responses to temperature and provide guidance for climate change adaptation, we evaluated long-term bloom records of 37 almond cultivars and 7 pistachio cultivars in Tunisia. Using Partial Least Squares regression, we delineated each cultivar's chilling and subsequent heat accumulation phases, and estimated chill and heat requirements by adding up all chill and heat accumulated during the respective periods. For both almonds and pistachios, temperatures during the chilling period were the dominant determinant of bloom dates. High temperatures during this period were associated with delayed bloom – a contrast to reports from other regions, which found a dominant bloom-advancing effect of warm springs.

Increasing occurrences of delayed flowering are a concern to Tunisia's growers, because late bloom has been associated with poor fruit quality and low yields. In some years, low winter chill completely prevented trees from breaking dormancy, leading to complete crop failure. While providing clear evidence that the production of temperate fruits and nuts in Tunisia is threatened by winter warming, this study also highlights shortcomings of existing tree phenology models, which currently restrict farmers' ability to anticipate chill-related problems and develop adequate adaptation strategies. The challenge of maintaining the productivity of Tunisia's orchards in a warming climate requires heightened scientific attention to dormancy-breaking processes and their responses to climatic factors.

**Keywords:** Chilling model, climate change, fruit and nut trees, Mediterranean region, PLS regression

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# Knowledge systems

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## Oral Presentations

- LORENZ PROBST, HYCENH TIM NDAH, PAULO RODRIGUES,  
GOTTLIEB BASCH, KALIFA COULIBALY, JOHANNES SCHULER:  
**From Adoption Potential to Transformative Learning around  
Conservation Agriculture in Burkina Faso** 294
- PAMELA NGWENYA, MARIA JOSE RESTREPO RODRIGUEZ,  
RAÚL FERNANDEZ, BRIGITTE KAUFMANN:  
**Participatory Video Proposals: A Tool for Empowering Farmer  
Groups in Transdisciplinary Innovation Processes?** 295
- GIANLUCA BRUNORI, EMIL GEVORGYAN, MANON LELARGE:  
**Integration of Local and Academic Knowledge to Enhance  
Agroecological Production of African Indigenous Vegetables  
(Kenya)** 296
- MST. SHARMIN AKTER, HARRO MAAT, CEES LEEUWIS:  
**Dissemination and Communication of Scientific Forecast  
Information and Advisory Services to Farming Communities  
in Jamalpur District, Bangladesh** 297
- FANOS MEKONNEN BIRKE, ANDREA KNIERIM, AZAGE  
TEGEGNE:  
**ICT-Based Platform for Facilitating Knowledge Access in  
Agriculture Extension Offices: A Case Study in Ethiopia** 298

## Posters

- GERBA LETA, GIRMA KELBORO, TILL STELLMACHER, ANNA-  
KATHARINA HORNIDGE:  
**Social Learning in Agriculture and the Battle against  
Systemic Inequalities: The Case of Southwestern Ethiopia** 299
- ANIKA MAHLA, KARIN GAESING, ANDREW KIPLAGAT:  
**Self-Help Groups and Empowerment of Rural Women.  
Evidence from Kitui, Kenya** 300
- LAURA BENDER, JULIA BOEDECKER, MARIA GERSTER-  
BENTAYA, ANDREA KNIERIM, CÉLINE TERMOTE:  
**The Use of Indigenous Knowledge for Nutrition Communica-  
tion: An Example of Pastoralists in Turkana County** 301

JONATHAN STEINKE, JACOB VAN ETTEN, MARK VAN WIJK: <b>Learning from the Most Successful: Prioritizing Rural Development Interventions by “Positive Deviance” Analysis</b>	302
ANDREW KIPLAGAT, ANIKA MAHLA, KARIN GAESING, ROSE LOKOYEL: <b>Innovating in the Fight against Poverty: Evidence from ‘Big-Push’ Interventions in Samburu County, Kenya</b>	303
DENISE MARGARET MATIAS, CHRISTIAN BORGEMEISTER, HENRIK VON WEHRDEN: <b>Ecological Changes and Local Knowledge Shifts in an Indigenous Honey Gathering Community in the Philippines</b>	304
MAXI DOMKE, JÜRGEN PRETZSCH: <b>Knowledge Management for Sustainable Agricultural Development. A Multi-Level Analysis of Obstacles and Potentials in Ethiopia</b>	305
ANTONIA ZAMPA, DIANA NAIKOKA, BARBARA SCHRÖTER, FRIEDER GRAEF: <b>Assessing Implementation Processes of Food Securing Innovations among Rural Farmers in Tanzania</b>	306
NATHALIE OBERSON, URS SCHEIDEGGER: <b>Participatory Variety Selection – Farmer Participation in Testing and Evaluating New Cultivars of Groundnut, Sorghum and Pearl Millet in Chad</b>	307
ISAAC MBECHÉ NYANG’AU, GIRMA KELBORO, ANNA-KATHARINA HORNIDGE, CHARLES MIDEGA, CHRISTIAN BORGEMEISTER: <b>Stakeholder Interaction and Social Learning: The Trans-Disciplinary Research Process in Push-Pull Technology Implementation in Ethiopia</b>	308
LISA JÄCKERING, THEDA GÖDECKE, MERCY WANJIRU MBUGUA, MICHAEL NJUGUNA, MEIKE WOLLNI: <b>How Does Social Capital Influence the Success of Development Projects? Insights from a Randomised Controlled Trial in Kenya</b>	309
MIRIAM ROMERO, KATRIN RUDOLF, MEIKE WOLLNI: <b>Promoting Trees at the Oil Palm Frontier: Experimental Evidence from Indonesia</b>	310
EMMA JANE LORD: <b>Schooling, Knowledge and REDD+, by Lake Tanganyika</b>	311
ANETT KUNTOSCH, BETTINA KÖNIG: <b>Systemic Barriers to the Adoption of Food Security Related Innovations – Three Examples from Tanzania</b>	312

KATHRIN MEINHOLD, NYORI JEREMIAH MBUGUA, ANTHONY MAINA, DIETRICH DARR, EL AMIN SANJAK, JOSEPH G. TUNJE, MWAMUYE POLE: <b>Baobab Production and Utilisation in Kilifi County, Kenya: Assessment of Information and Training Needs</b>	313
ANJA SCHELCHEN, NICOLE PAGANINI: <b>Innovation and Knowledge Exchange Systems: The Case of Urban Agriculture in Maputo and Cape Town</b>	314
ESTHER MIEVES, PAMELA NGWENYA, BRIGITTE KAUFMANN: <b>Farmers' Views on Innovation Outcomes: Participatory Outcome Evaluation with Smallholder Farmer Groups in Tanzania</b>	315
CYNTHIA ADDOQUAYE TAGOE, ANTOINETTE TSIBOE-DARKO, FELIX A. ASANTE, MAKAFUI DZUDZOR: <b>Gendered Roles in Yam Cultivation and Food Security in West Africa</b>	316
SERGIO ALEJANDRO URIOSTE DAZA, EMIL GEVORGYAN, MARIJKE D'HAESE: <b>Monitoring and Evaluation of Transdisciplinary Food Security Interventions in Kenya</b>	317

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## From Adoption Potential to Transformative Learning around Conservation Agriculture in Burkina Faso

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Despite the substantial support of donors and development agencies, Conservation Agriculture (CA) has not moved from an invention to an innovation stage in sub-Saharan Africa. The results of the common strategy to transfer the technology from science through donors to farms in a top down manner have been disappointing (with Burkina Faso being a typical case). To make things worse, assessing the actual levels of adoption has been problematic due to the biases and weaknesses of the applied methods - including the Qualitative expert Assessment Tool for CA adoption in Africa (QAToCA). However, to promote sustainable farming pathways such as CA, we still see a need for methods that help to understand and foster transitions in agricultural practices. The purpose of this work is thus to design an approach that combines current insights in learning theory and practice. The starting point of the process is an assessment of the agro-ecosystem health of the farming system of interest, by exploring the social, economic and ecological characteristics of the system. Second, to create space for social learning, we apply participatory stakeholder mapping to make the roles, values, interests, and capabilities of the different stakeholders explicit. Third, the stakeholders jointly work on a historical timeline of CA promotion to identify key events, drivers and constraints of the innovation process. Then, to support individual experience, dialogue and different ways of learning, the stakeholders together create non-scripted, non-edited videos of their perspectives on challenges in the farming system. These videos are then screened in a multi-stakeholder meeting to stimulate the discussion on the innovation potential of CA. Discussions are structured by the framework of QAToCA. The results of all exercises feed into a proposal for an improved promotion of CA. We tested the approach in a farming community in Koumbia, Burkina Faso. The described learning elements helped to moderate the expert bias and rigidity of QAToCA. As a learning outcome, the results underlined that CA uptake will depend on the adaptation to the local conditions (e.g. competition over crop residue exacerbated by free-grazing) in order become a viable agricultural system.

**Keywords:** Adoption, conservation agriculture, participatory video, transformative learning

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## Participatory Video Proposals: A Tool for Empowering Farmer Groups in Transdisciplinary Innovation Processes?

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With the intention of developing more democratic processes of knowledge production to support innovation processes, a critical methodological approach was developed within the frame of two transdisciplinary “research for development” projects in Kenya and Tanzania. In the discovery phase of the transdisciplinary projects, five smallholder farmer groups were invited to apply for action funds to co-develop innovations to enhance livelihoods. Employing participatory video (PV), groups applied for the grants using a ‘video proposal’. Group members collaboratively produced videos representing their problems, aims and innovation plans. The underlying motive of this approach was to strengthen the role and the decision-making power of the farmers in the research process, to support them in jointly conceptualising innovation processes, while at the same time creating a ‘space of inclusion’ in which power relations could be renegotiated.

However, power and empowerment are fuzzy concepts and have been variously theorised in terms of “power-over”, “power-to” and “power-with”. With regard to these three modalities, this presentation critically examines how power relations were affected by the PV proposal process with particular attention to: i) researcher-participant relations, ii) intra-group relations, and iii) group-community relations. We then critically address the question: “in how far are PV proposals a tool for empowering farmer groups in transdisciplinary innovation processes?”

A qualitative approach was employed to gain insight into farmers’ perspectives. This included 40 semi-structured interviews and 5 narrative interviews. Initial observations conveyed the process as contributing to empowerment with regard to enhancing group ‘capacities to act’, in terms of strengthening group members’ pride in, control over and sense of ownership of their innovation processes. However a more critical understanding of power enables one to highlight the context-specific limitations to empowerment, including issues of patronage, gender norms, project longevity and economic circumstances. In conclusion, the method presented can serve as a useful tool for supporting transformative processes of knowledge co-production and action research, and has cautionary possibilities for supporting empowerment processes.

**Keywords:** Empowerment, farmer groups, innovation processes, methods, participatory video, transdisciplinarity

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## **Integration of Local and Academic Knowledge to Enhance Agroecological Production of African Indigenous Vegetables (Kenya)**

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Agricultural development in the past decades was focused on disseminating high yielding crop varieties, promoting the use of inputs such as chemical fertilisers or standardising technologies as a solution-package to address low productivity. On top of causing biodiversity erosion and disruption of local ecosystems, this approach led to the loss of traditional knowledge and know-how regarding indigenous crop production.

In 2013 the HORTINLEA research project took interest into AIVs as a way forward to improve livelihood and nutritional situation of eastern African farmers'. Since these vegetables were produced as subsistence crops in East Africa for generations, it was of utmost importance to document sustainable local practices before their extinction and to enhance them through their integration into academic knowledge system.

In order to promote this knowledge integration, and to contribute to the edition of a guidelines' manual to be disseminated throughout East Africa, a qualitative approach was adopted. Twenty two farmers from Western Kenya were interviewed, with a focus on their agricultural and consumption practices, as well as challenges and sources of knowledge. Thirty two academics, mainly from Central and Western Kenya, were questioned on their perception of AIVs challenges and opportunities, as well as on current knowledge transfer methods and suggestions for improvement. Two focus group discussions provided insight on farmers and academics interactions and opened a window of opportunity to improve the situation.

A set of sustainable practices were identified for each step of the AIVs production process. These practices, embedded in a given environment submitted to several challenges, are facing possible disruption. However, a clear synergy between local and academic knowledge was identified and by complementing each other's knowledge gaps, farmers and academics could be able to overcome them. AIVs' potential can be tremendous, especially regarding their nutritional content and marketing opportunities, and thus a bright future seems to await their consumers and producers. By promoting the adoption, at a small-scale level, of sustainable and efficient AIVs production practices, emerging from the integration of local and academic knowledge, a step towards food security and better nutrition could be reached in Kenya, and in East Africa.

**Keywords:** Academic knowledge, African indigenous vegetables, agroecology, East Africa, integration, local knowledge, practices

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## **Dissemination and Communication of Scientific Forecast Information and Advisory Services to Farming Communities in Jamalpur District, Bangladesh**

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This paper explores how development agencies disseminate and communicate science-based forecast information about flood and climate risks and related advisory services to farm communities. In particular we analyse dissemination approaches and ways in which development agencies interact with farmers to enhance their capacity to use forecast information. For this study we used the skilling concept, understood as a combination of social and environmental learning. With this methodology we seek to identify what kind of interactions are employed by development agencies, on what basis participants are selected, how stakeholders of different agencies interact with the farmers and how participants perceive the effectiveness of different approaches and forms of interaction about flood and climate risk management. The research was carried out in three different villages in the Jamalpur district of Bangladesh. Fieldwork in the three villages was conducted through participant observations and in-depth interviews with different concerned stakeholders and participating farmers to explore how forecast information and advisory services were disseminated and communicated by development agencies. The results make clear that there is substantial variation in dissemination methods and forms of communication among the development agencies. The intensity and frequency of interactions between agencies and farmers seemed not to matter much for the achieved skilling. In particular when different streams of information came from different sources and when participation in dissemination activities was not representative for the farm population. We conclude that a lack of adequate coordination among development agencies to disseminate and communicate similar types of forecast information and advisory services enhances the chance of communicating inconsistent information to farm community. Therefore, we suggest that agencies reconsider effective learning strategies, most prominently by evaluating linkages and coordination between agencies to disseminate and to communicate consistent forecast information and advisory services.

**Keywords:** Advisory services, Bangladesh, communication, dissemination, scientific forecast information

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## ICT-Based Platform for Facilitating Knowledge Access in Agriculture Extension Offices: A Case Study in Ethiopia

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Challenges in integrating Information and Communication Technologies (ICTs) into agricultural extension service delivery in developing countries are common. However, effective approaches that look into the sociotechnical systems of ICT services implementation and use at the organisational level are yet to come. Agricultural knowledge centres (AKCs), platforms that allow access to ICTs for online and offline knowledge and communication resources, were piloted in selected four regions of Ethiopia in the past decade. This research documents the challenges and opportunities of establishing AKCs by the Livestock and Irrigation Value Chains for Ethiopian Smallholders (LIVES) project and the agricultural extension offices that owned it ultimately. Data were collected through in-depth interviews with key actors that took part in the implementation and operationalisation processes as well as archival resources that documented the process. The study is framed by the perspectives of Actor Network Theory to document the interaction of social and technical factors in the processes of establishing AKCs. Results showed that integrating AKCs into the organisational structure of public agricultural extension offices for the purpose of knowledge sharing and communication was challenging from the start. The limited awareness on the appropriateness of AKCS for the provision of knowledge resources and information services in a complex socio-political context of agricultural extension offices resulted in the partial success of AKC services operationalisation. Hierarchical organisational structure and institutional system of the public sector brought challenges to make adjustments with regard to financial resource allocation and operationalisation of the AKC services. Additional but not accounted for responsibility given to unmotivated managers of the centres influenced the service quality the AKC offered. This study recommends the need for a closer look on the appropriateness of ICT initiatives in a context by looking at organisational goals and objectives as well as the service delivery systems, human resource capacity, and availability as well as the critical need for such initiatives.

**Keywords:** Ethiopia, extension, ICTs, information, knowledge, sociotechnical systems

## Social Learning in Agriculture and the Battle against Systemic Inequalities: The Case of Southwestern Ethiopia

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While Ethiopia maintains a large agricultural extension service system, access to extension knowledge and its resources is largely limited to model farmers, as parts of the rural elites. In consequence, social learning is widely practiced as an inherent coping mechanism to the segregated distribution of knowledge, technologies and agricultural inputs. Despite the widespread use of social learning for knowledge and technology transfer, it has so far hardly been documented in the context of rural Ethiopia or analysed with reference to the translation and adaptation processes through which the passed on knowledges are embedded into the local system of knowledge production and sharing. The purpose of this study is, therefore, to identify the different methodological types of social learning as well as their contribution to innovation development and diffusion within the agricultural context of Ethiopia. A mixed methods approach was employed using household surveys, expert interviews, focused group discussions, informal discussion as well as key informant interviews. The data were documented, coded and analysed using SPSS and ATLAS.ti. The findings show that 55 % of the farmers in the case study area fully relied on social learning to adopt technologies followed by 35 % who partly use social learning. Overall, about 90 % of the farmers acquire knowledge through social networks and by means of communication, observation, collective labor, public meetings, social events and group socialization. Social informal institutions such as Iddir, and collective labour groups, notably *Debo* and *Dado*, help to learn, adopt and diffuse technologies where the formal extension services is rather limited to model farmers, which account for only about 10% of all farmers in southwestern Ethiopia. Social events and group socialization with peers along with the inherent tradition of seed and knowledge sharing stimulates diffusion of new knowledges and technologies. Based on the empirical findings, we suggest that social learning substantially contributes to resource poor farmers and other majorities to access knowledges and technologies mainly through their interaction. It serves as a coping mechanism to the prevailing limitations, but at the same time stabilizes a knowledge system that allows for the further fostering of social, political and epistemic inequalities.

**Keywords:** Communication, group socialisation, observation, social events

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## **Self-Help Groups and Empowerment of Rural Women. Evidence from Kitui, Kenya**

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After the great success of self-help groups (SHG) in India the approach was exported to several African countries. In this context, the German non-governmental organisation Kindernothilfe financed the so called Fumbua Uwezo Project through their Kenyan partner Kitui Development Center. The project aims to mobilise rural women to start saving and thereby unleash their human potential for achieving empowerment of individuals as well as the community in social, economic and political terms in a bottom up process. The article shows how the application of participative poverty analysis contributed to the targeting of ultra-poor women and in how far they profited from the project where they received different trainings on group building, saving/borrowing, agriculture and starting small businesses. The field study used a mixed method approach which consisted of focus group discussions, income- and expenditure rankings, expert interviews and a household survey with over 400 participants. The results demonstrate that beneficiaries particularly profit because, with the help of credits from the SHG, they were able to pay school fees, improve their livestock and purchase inputs for farming. The SHG also improved the access to food and water, led to a rise and diversification in income and strengthened the social cohesion and resilience of the community. The grassroots democracy structure of the SHG operates on three levels by tackling social, economic and political challenges on an adequate scale. The poster will also reflect on challenges like management of the burden of loan repayment and it formulates recommendations for improving the promising approach.

**Keywords:** Empowerment, poverty alleviation, rural development, self-help, women

## The Use of Indigenous Knowledge for Nutrition Communication: An Example of Pastoralists in Turkana County

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Indigenous knowledge increasingly gains interest as an important aspect in development, particularly in the case of people living in marginalised regions like Turkana County in northern Kenya. To date, however, such knowledge is underutilised in the context of development activities, especially, in the field of health care and nutrition. Bioversity International is a non-governmental research for development organisation engaged in projects addressing agrobiodiversity conservation in the Turkana region in Kenya. Bioversity and the University of Hohenheim jointly conducted a study to investigate the potential utilisation of indigenous knowledge for nutrition communication focussing on local narratives and local institutions that store and transmit knowledge. The objectives were: 1) to detect certain educative messages in local narratives, 2) to assess what positive aspects of the local knowledge system can be utilised in nutrition communication, and 3) to explore local populations' as well as external administrative stakeholders attitudes and perceptions towards indigenous knowledge. In April 2016, twelve Focus Group Discussions involving the local population were conducted. Additionally, eleven structured Expert Interviews with different stakeholders from government or NGOs were conducted in July - August of the same year. The findings demonstrate local people's strong connection and appreciation of indigenous knowledge and the people who store and transmit it. Only few nutritional messages could be detected in local narratives, but, upon request, crucial knowledge about nutrition was available at community level. Local decision makers are partly aware of the potential use of indigenous knowledge systems and some examples of incorporating nutrition-related messages in local narratives were mentioned. The overall attitudes towards the utilisation of indigenous knowledge systems were positive. Stakeholders grown up in the particular cultural setting of Turkana are even more aware of the potential use of local knowledge. Lastly, the local population calls for an acknowledgment of their inherent culture, traditions and knowledge.

The findings, therefore, support the use of indigenous knowledge systems and local narratives in special, as a well-adapted means to deliver nutrition-related messages in Turkana County.

**Keywords:** Cultural-centric narratives, indigenous knowledge, Kenya, nutrition communication

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## Learning from the Most Successful: Prioritizing Rural Development Interventions by “Positive Deviance” Analysis

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Rural households in developing countries pursue multiple livelihood goals simultaneously, such as food security, income, and a healthy nutrition. These goals are often dynamically interconnected, meaning that development interventions targeted at improving one livelihood domain may cause concurrent losses in another. Researchers and policy-makers have answered calls for holistic, integrated development by formulating new paradigms, such as ‘sustainable intensification’, yet without prescribing concrete strategies. Hence, which innovations and practices lead to the desired changes in specific context remains to be determined.

System modelling is a widespread strategy to integrate different livelihood domains, and make *ex-ante* predictions about the outcomes of specific technological or institutional interventions. But models are subject to uncertainty and incompleteness, and frequently suffer from narrowly defined system boundaries. These limitations make it difficult to derive concrete recommendations for rural development interventions.

To support the selection of intervention strategies for holistic development, we propose an alternative approach. The “positive deviance” concept rests on the observation that, in many rural communities, some households achieve higher livelihood success than others, although facing similar resources, challenges, and trade-offs. These positive deviant households (PDs) likely do things differently, be it farm management, resource allocation, or off-farm activities. We suggest that involving PDs in empirical, qualitative research may reveal successful and potentially uncommon behaviours embedded in local context. These may be crucial inputs to meaningful development interventions.

We designed a methodology for identifying PDs, using a lean data approach and based on household success in five key livelihood domains. We surveyed 521 rural households in Tanzania, identifying 54 PDs. Here, positive deviance chiefly stemmed from success in nutrition, income, and low environmental impact. Interventions in these domains are thus more promising than interventions for food security or gender equity. We also systematically selected 18 PDs for in-depth interviews and farm visits, revealing several on- and off-farm success strategies, such as investments into crop storage, and meticulous allocation of labour resources during periods of land preparation and sowing.

This pilot study demonstrates the potential of positive deviance analysis for rapid prioritisation of rural intervention options, grounded in the real-life experiences of the target population.

**Keywords:** Development interventions, lean data, positive deviance, research methods, sustainable intensification

## **Innovating in the Fight against Poverty: Evidence from ‘Big-Push’ Interventions in Samburu County, Kenya**

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Poverty and food insecurity in Kenya are endemic problems. Official records show that the fight against poverty has been a developmental issue since independence. Yet even at this present moment, more than half of the population especially in rural areas of Kenya is living in poverty. A case example is Samburu, a county ranked sixth poorest with a poverty incidence of 71 %. Besides being poor and food insecure, this county experiences insecurity due to frequent attacks from neighbouring pastoralist communities which occur especially during recurrent drought. This paper uses findings from a study of SAPLIP (Samburu Livelihood Improvement Project), a project funded by EU and implemented by World Vision Kenya in cooperation with the National Drought Management Authority (NDMA), to show how a ‘big-push’ can contribute to reduction in poverty and food insecurity. The study employed focus group discussions, intensive key informant interviews and a household survey on 373 households consisting of 203 project participants and 170 non-participants. This study established that SAPLIP made concurrent interventions at different levels to tackle poverty, food insecurity and to enhance drought resilience. Specifically, the project targeted the promotion of peace in the region, the promotion of group socio-economic activities to improve member’s income situation and the promotion of sustainable agriculture at household level to attain food security. Furthermore, SAPLIP introduced methods of natural resource management, e.g., planting of multi-purpose trees. Findings show that respondent’s state of livelihood has greatly improved and are more resilient with regard to drought. They make income from their group activities, including horticultural production in green houses and bull-service offered to other community members. Their households are also food secure due to the additional agricultural production skills they acquired from the project and because of the increasing peace in the locality. The paper concludes that appropriate multi-level and multi-sectoral interventions targeting regional, inter and intra-household determinants of poverty and food insecurity are critical for success in the fight against poverty and food insecurity.

**Keywords:** Big push, innovating, Kenya, multi-sectoral, poverty and food insecurity, Samburu

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## Ecological Changes and Local Knowledge Shifts in an Indigenous Honey Gathering Community in the Philippines

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One of the traditional livelihood practices of indigenous Tagbanuas in Palawan, Philippines is wild honey gathering from the giant honey bee. In order to analyse the linkages of the social and ecological systems involved in this indigenous practice, we conducted spatial, quantitative, and qualitative analysis on field data gathered through GPS mapping, community surveys, focus group discussions, and key informant interviews. We found that only 24% of the 251 local community members surveyed could correctly identify the giant honey bee. Inferential statistics showed that a lower level of education and higher household vegetation contribute to correct identification of the giant honey bee. Spatial analysis revealed that mean NDVI of sampled nesting tree areas has dropped from 0.61 in the year 1988 to 0.41 in 2015. This reduction on vegetation cover may contribute to reduced bee-human interactions and may also be an indication that commercialising non-timber forest products is not fulfilling its objective of development alongside conservation. Indigenous wild honey hunting and gathering as an ICDP shows the complexity of the social-ecological system of forest communities. It also shows the difficulty of getting a win-win situation out of simultaneous pursuit of forest conservation and rural development. Knowledge shifts can, indeed, occur from the interaction of ecological and social factors and we see that if resource management interventions do not employ a systems approach, it can overlook important feedback. NGO interventions should not only facilitate the learning of visible resource managers like wild honey hunters but of the community as a whole.

**Keywords:** Local knowledge, social-ecological system, spatial analysis, wild bee

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# Knowledge Management for Sustainable Agricultural Development. A Multi-Level Analysis of Obstacles and Potentials in Ethiopia

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This study investigates knowledge management obstacles and potentials within the institutional and social system for agricultural and natural resource management in Ethiopia. The objectives are 1) determining the institutional framework and collaboration, 2) analysing the capacity of the extension system and training activities for knowledge generation and transfer, 3) investigating local thresholds for information access and knowledge exchange.

The explorative study was carried out from 2013 to 2015. A single case study design was applied with Ethiopia incorporating the national and local level as embedded units. Data was collected by reviewing official documents, conducting 80 interviews with state and civic organisational representatives and a survey with 112 community members in Amhara and Oromia Region. Stakeholder and communication analysis was applied.

Findings show that Ethiopia's national strategies on economic growth and climate change adaptation are elaborated by the government with minor involvement of non-government stakeholders and lower administrative levels. The national institutions for environment and climate change are not reflected at the regional level which results in a gap of information flow and unclear responsibilities. The top-down and sector-focused structure of the government system impedes multi-stakeholder collaboration and information transfer fitting to local contexts. Trainings on agricultural and environmental rehabilitation activities are offered to local stakeholders and community but the content and methods are partly not matching with the demand. Information structures of the extension system are primarily one-way. Very basic local living and working conditions induce a brain drain of qualified local staff and community members leading to a loss of knowledge and manpower. Half of the community members face challenges in accessing information and communication due to remoteness and lack of communication means. Women have a limited social network and access to information due to traditional gender patterns.

Narrowing the gap between governance and action requires a mutual understanding by the relevant actors. Platforms for multi-level stakeholder dialogue can facilitate access to information, knowledge exchange and the production of new knowledge. Prerequisites are vertical and horizontal institutional linkages, and the sharing of decision-making power and responsibilities.

**Keywords:** Communication analysis, Ethiopia, extension, governance, multi-stakeholder collaboration

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## Assessing Implementation Processes of Food Securing Innovations among Rural Farmers in Tanzania

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Food security is a major challenge in developing countries, especially in sub-Saharan Africa, where smallholder farmers, are particularly affected by climate change. A transformation of their livelihood along sustainable pathways is vital for building resilience.

The participatory research project Trans-SEC addresses this issue by implementing upgrading strategies (UPS) for improving food security among the most vulnerable rural population in Tanzania. The UPS were selected by involving all stakeholders and implemented in villages of the sub-humid Morogoro and semi-arid Dodoma region.

For ensuring successful and sustainable implementation it was found essential, understanding stakeholders' motivations during implementation, identifying challenges faced in the implementation and analysing the UPS adoption rates.

This study focused on six UPS: Rainwater harvesting, improved processing (maize sheller and millet threshing machines), improved firewood cooking stoves, kitchen gardens with green leafy vegetables, poultry-crop integration, and optimised market oriented storage. Social Network data was collected using the SNA tool Process Net-Map, to analyse and understand the hurdles of implementation processes. The tool visualises on a social Net-Map the implementation processes, actors, and activities showing entry points for challenges. Perceptions of the actors involved were obtained on five pre-selected criteria of influence, food security, income, knowledge transfer and trust. Also, narratives were obtained by interviewing both local stakeholders and scientists involved in the UPS implementation.

Results show success stories, good practices and challenges in the implementation and potential sustainability of the UPS. We found out, for instance, that the kitchen gardens and nutrition education increased knowledge and awareness about the importance of vegetable consumption and the need to diversify diets to reduce nutrient deficiencies. Tied-ridges were associated with knowledge on increased water retention on farm plots especially in semi- arid Dodoma. Poultry crop integration and improved storage bags was associated with increased household incomes and overall food security. Challenges due to lacking transparency occurred during the use of improved processing machines. The improved cooking stoves groups in every village reveal high degrees of motivation and ownership of that process.

**Keywords:** Food security upgrading strategies, process Net-Map, storylines of implementation processes, Tanzania

## Participatory Variety Selection – Farmer Participation in Testing and Evaluating New Cultivars of Groundnut, Sorghum and Pearl Millet in Chad

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In Chad, like in many developing countries, seed saving is important. Chadian farmers apply positive mass selection to produce their own seed. They are keen to try new varieties, yet access is limited. The project “Opérationnalisation de la filière semencière au Tchad”, financed by the Swiss Agency for Development and Cooperation, seeks to improve access of small-scale farmers to quality seed of appropriate varieties in view of improving their food security and income.

In 2016, the project helped the Agricultural Research Institute of Chad to introduce a broad range of cultivars of groundnut, sorghum and pearl millet from neighbouring countries. The first evaluation of this material was done in farmers’ fields using participatory variety selection. Farmers tested all new cultivars in their fields under their own practices at sixteen different sites across the southern and the eastern part of Chad. Before harvest, around 30 farmers per site evaluated the varieties.

The evaluations showed that farmers appreciate several of the new cultivars and provided insights about their preferences: Farmers who assessed sorghum cultivars in the South of Chad prefer long and large panicles with “a lot of grains”. They appreciate erected and goose-necked panicles, as these are less attacked by birds. White and grey grains are appreciated for cooking of traditional dishes whereas red grains are preferred for local beer brewing. To farmers it is important that the grains can easily be removed from the glumes. They appreciate both fine stems for livestock feeding and strong stems for construction. Farmers are interested in sorghum varieties with sweet stems because they can sell the stems in local markets. The evaluations also yielded a rich body of insights into farmers’ preferences and selection criteria for pearl millet and groundnut.

In 2017, the most preferred varieties are tested in multi-locational trials and at the same time introduced into seed multiplication for later diffusion.

**Keywords:** Chad, farmers’ preferences, participatory variety selection, seed systems

## Stakeholder Interaction and Social Learning: The Trans-Disciplinary Research Process in Push-Pull Technology Implementation in Ethiopia

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In the Ethiopian agricultural research – extension system, contribution of smallholder-farmers to find practical solutions to problems facing the agricultural sector is not fully harnessed. This study was implemented between August 2014 and April 2015 to illustrate the importance of stakeholder interaction using the Push-Pull Technology (PPT) to address the problem of the stemborer in maize in Bako Tibe, Jimma-Arjo and Yayu Woredas of Oromia, Ethiopia. In our study areas, maize was inter-cropped with a fodder legume, *Desmodium* (the push), together with an attractant trap plant, Napier/*Brachiaria* grass (the pull), planted around maize-legume inter-crop. The data was collected through 37 key informant interviews, 20 Focus Group Discussions, 2 workshops, participant observations and questionnaire interviews of 227 farmers. The findings showed the possibility of joint agricultural innovation development. On-farm implementation of PPT with the involvement of the multiple stakeholders created an opportunity to interact, learn from each other and appreciate the respective contributions. This was unlike the conventional linear communication from research-extension agents to farmers. The long-term nature of PPT implementation over several cropping seasons provides sufficient time-lines for continuous learning and interaction. This was an opportunity for the stakeholders to clear doubts and suspicions they had at the beginning. The stemborer pest problem which had no previous promising solution was a strong motivation for the stakeholders' willingness to collaborate, share knowledge and experiences and to learn more. The use of farmers' fields enabled critical assessment, relaxed learning and appreciation of PPT. The PPT introduction was also a cause of conflicts with traditional practices such as inter-cropping cereals with perennial crops and roaming livestock during off-cropping season. This required change of the tradition established over generations. Despite short period of the study, the stakeholders appreciated PPT as a remedy to deal with the stemborer, a source of fodder and improving soil fertility. We consider adaptation to the new condition as part of the social learning process. However, they need 2–3 cropping seasons to learn and effectively assess PPT benefits. Therefore, research and follow-up are needed on the adaptation of the technology components to local needs and sustainability of the required inputs.

**Keywords:** Ethiopia, push-pull technology, social learning, stakeholders, trans-disciplinary research process

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## How Does Social Capital Influence the Success of Development Projects? Insights from a Randomised Controlled Trial in Kenya

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Social capital plays an important role for the adoption of agricultural technologies and can therefore positively influence farmers' livelihoods. One dimension of social capital refers to the way people are embedded in their networks. Common-interest groups (CIGs) are important information networks used for channeling agricultural extension programs. CIGs are chosen with the rationale of reducing transaction costs. Though, little is known about how the social capital of a CIG, as well as the social capital of individuals embedded in them, can determine projects' successes. Therefore, this study aims to investigate the flow of agriculture and nutrition information within CIGs, how initial social capital on CIG and household level changes through the introduction of a development project and how social capital influences the project's success. The results can help to improve the targeting of CIGs and individuals and increase the impact of nutrition-sensitive agricultural projects. The analysis is based on a clustered randomised controlled trial (RCT) implemented in rural Kenya. Forty-eight CIGs were randomly sampled. Out of each group, a random sample of 20 members was drawn. The treatments were carried out in 2016 and consisted of varying combinations of agricultural and nutrition training. Overall, 36 groups received training held by local extension officers. The broader purpose of the extension training was the promotion of pro-nutrition innovations. Survey data, including detailed information about social networks from 824 households was collected before (2015) and after (2016) the intervention. The analysis is performed on group and on individual levels. To proxy social capital, we rely on concepts such as network density for different types of relation (e.g. information exchange about agriculture and nutrition). The concepts used originate from social network analysis' literature. For the econometric analysis, we use project's success as our dependent variable measured by participation in training, and adoption of the promoted technologies. First results on group level suggest that groups with initially high social capital have higher participation rates in training sessions.

**Keywords:** Extension, common-interest groups, nutrition-sensitive agriculture

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## Promoting Trees at the Oil Palm Frontier: Experimental Evidence from Indonesia

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Oil palms are expanding rapidly in Sumatra, Indonesia. Numerous studies have shown the negative environmental effects of the conversion of forests and formerly diverse agricultural landscapes into oil palm monocultures. To counteract the decline in ecosystem services and biodiversity, planting of native tree islands has been proposed. While the positive ecological effects are well documented, only few small-scale farmers in Sumatra enrich their plantations with native tree species. Identified adoption barriers consist both of a lack of knowledge about the benefits and the management of native trees in oil palm plantations and of structural obstacles like missing seed markets. Possible policy tools to overcome these barriers are informational and structural interventions.

The current study addresses the question of how the adoption of native trees can be promoted among small-scale oil palm farmers in Sumatra. To investigate the impact of informational and structural interventions on farmers' perceptions and actual adoption of native trees, we conducted a randomised controlled trial in 2016. We implemented two treatments: an information campaign and an additional provision of saplings to overcome missing markets for seed material. The information campaign consists of an extension session during which a movie was screened and an illustrative manual provided. Additionally, each participant of the session was provided with a selection of six native saplings in the structural intervention.

Our study covers 36 randomly selected oil palm growing villages, of which 12 were randomly assigned to receive the information campaign only and 12 to receive both the information campaign and the structural intervention. Survey data from 820 households was collected before and after the intervention. Additionally, data on actual tree planting behaviour was assembled during a follow-up in late 2016. Results show a positive effect of the information campaign on the perceived provision of ecosystem services by native trees and on the intention to plant trees in oil palm plantations. Stated demand for saplings is only higher among farmers who received saplings in addition to the information campaign. Analyzing the impact of the interventions on actual tree planting behaviour is still work in progress.

**Keywords:** Indonesia, informational intervention, oil palm, perception, randomisation, structural intervention, tree planting

## Schooling, Knowledge and REDD+, by Lake Tanganyika

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Co-benefits put the + on the end of Reducing Emissions from Deforestation and forest Degradation (REDD+), conceptualised as a triple win for climate, biodiversity and communities. Yet natural systems, such as forests, are increasingly being recognised as dynamic and complex, as opposed to reductionist, analytical worldviews of science. Decisions over what, or who to observe become distorted over multiple scales of analysis. How can policy makers know what takes place on the ground? Scholars have predicted – when introduced into contexts of unequal access to capital, labour and credit – REDD+ will be biased against the interests of rural communities and maximise exploitation by elites. Sociologically speaking, how does this process take place? This article focuses on how power dynamics, social-political relations and technical expertise shape REDD+ financial distribution, looking specifically at excluded actor groups and their interactions with the forest conservation planning and management process. Analysis is based on five months of observation and comprehensive interviews at a REDD+ pilot site, on the western Tanzanian border, interviews in Morogoro and Dar es Salaam. Understanding organisations as human constructs, we approach the global policy of REDD+ as itself constituted within a concrete local project, within a real international conservation NGO, their practices and interactions with communities, politicians, experts and intermediately actors linked to global hierarchical chains. This case shows how the introduction of parallel institution by donors and international organisations has created complex institutional arrangements. Furthermore, the technical knowledge requirements of REDD+ fragmented the local arena through the introduction of a specialised team whose interests competed with the international NGO who created the pilot project. This highlights the need for observation from a social, as opposed to biophysical perspective as a crucial and overlooked stage in the implementation and evaluation of REDD+.

**Keywords:** Biodiversity, climate mitigation, co-benefits, elite capture, pastoralists deforestation, REDD+, safeguards

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## Systemic Barriers to the Adoption of Food Security Related Innovations – Three Examples from Tanzania

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Food insecurity remains a persistent problem, affecting one-third of Tanzania's population. Additionally, strong population growth and impacts of climate change hindering agricultural activity make the situation more acute. Hence, the issue has likewise received attention from scholars, NGOs, practice, government and associated bodies. To approach such complex – multi-level and multi-entry point – problems as food security, innovation is discussed as one possible solution. Notwithstanding many cases of successful innovation uptake, data from the field still indicate limitations to the adaptive and innovative capacity of specific food-insecure groups, such as small-scale farmers in drought-prone regions. As a result, usage of improved seed and fertiliser, mechanisation of agricultural production or necessary change of eating habits often remain at low level. While the reason for failed adoption is often presumed to be rooted in individual adoption behaviour, this contribution aims to reveal site-specific adoption barriers arising from “the making” of innovation processes. To analyse the innovation processes and reveal possible adoption barriers for three example innovations, we use an alternating sequence and consecutive analytical steps between the micro- (individual) and the macro- / meso- (system) level. The three selected food security innovations improved cooking stoves, fertiliser micro-dosing and kitchen gardening were introduced to nine small-scale subsistence farmer groups in three villages in rural Tanzania in the frame of a German-Tanzanian trans-disciplinary action research project. The selected case study sites represent two typical agro-ecological settings in sub-Saharan Africa: a semi-arid region (Dodoma) and semi-humid region (Morogoro). The changing conceptual perspective and case diversity allows for a better understanding of the individual adoption decisions and examines how feedback is given into the system. We use a mixed-methods approach including literature review, semi-structured expert interviews and farmer group discussions with nine farmer groups. Summing up, this approach assists understanding of the complex, multilevel-interactions that make up for food security innovation processes in the given context, and point to possible system adjustments for further improvement of such innovations; needed to arrive at a more sustainable adoption behaviour and thus, improved food security status.

**Keywords:** Adoption decision, food security, innovation processes, multi-level, small-holder-farmers

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## Baobab Production and Utilisation in Kilifi County, Kenya: Assessment of Information and Training Needs

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The baobab tree (*Adansonia digitata* L.) occurs naturally throughout the drier parts of sub-Saharan Africa and has traditionally been used as a food source. The fruit pulp in particular is of high nutritional value, featuring high contents of vitamin C, minerals, as well as prebiotic and antioxidant functions. However, in Eastern Africa the species is regarded as underutilised as its potential for improving local diets and livelihoods is not yet fully exploited. Baobab management and processing for value addition and marketing initiatives are scarce while extension services currently do not address sustainable baobab management, processing and utilisation activities. This study investigated the gaps in knowledge and information relating to the management of baobab trees and utilisation of baobab products in rural communities in Kilifi County, Kenya. 120 households were selected using a systematic random sampling technique. Preliminary results demonstrate that although the majority of households (69.2 %) owned baobab trees on their farms, most farmers only had limited knowledge on baobab tree management for the entire production cycle from nursery establishment to post-harvest treatment, on the various types of products that can be obtained from baobab trees including their value, as well as on potential marketing pathways. The study revealed that only 34.2 % of respondents have been involved in making one or more baobab products, and less than 10 % engaged in any form of baobab management practises. Only 15 % of the respondents used the baobab fruit pulp as a source of food despite its valuable nutritional properties. Over 70 % of the sampled households did not receive any kind of agricultural information, indicating the potential for improving current practises. The study will guide the development of tailor-made extension materials and trainings which will address the gaps of information and knowledge and enable communities to successfully adopt sustainable baobab management and processing techniques and technologies.

**Keywords:** Baobab (*Adansonia digitata* L.), information needs, training needs assessment, underutilised plant species

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## **Innovation and Knowledge Exchange Systems: The Case of Urban Agriculture in Maputo and Cape Town**

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The international community set the goal “Zero Hunger” as one priority in its global commitment of achieving the Sustainable Development Goals by 2030. One priority is given to urban areas; cities are growing fast but economically highly unequal and access to safe and healthy food remains problematic. Sub-Saharan Africa is the most rapidly urbanized region in the world, especially in the urban informal areas. In this context, urban agriculture has been a popular response in contributing to income generation and food and nutrition security and has come into the focus of scientific research.

The aim of this study is to investigate innovation and knowledge exchange systems to identify successful ways of dissemination for organic cultivation methods in the city of Cape Town and Maputo. For this purpose, we use the Innovation System Approach, where we look at all involved stakeholders in the innovation process, their role, networks and applied knowledge exchange mechanisms. Using an action research approach and based on qualitative and quantitative data obtained from the urban farmers and main stakeholders, the study looks at ways of agroecological practices, challenges and constraints of production and commercialisation. We also expect to find out what are the reasons and motivations for farmers to adopt those practices.

The assessment of innovation and knowledge exchange system allows us to identify drivers and barriers for a successful dissemination. Based on the results, a multiplication strategy can be developed and results could be transferred to policy makers and urban planners. Considering the vision of making urban agriculture more sustainable, this can contribute to urban food and nutrition security on the one hand, and on the other hand to a more sustainable city in terms of environmental friendly areas with benefits for the community.

**Keywords:** Agroecological practices, food and nutrition security, innovation system approach, participatory guarantee system, Southern Africa, urban agriculture

## Farmers' Views on Innovation Outcomes: Participatory Outcome Evaluation with Smallholder Farmer Groups in Tanzania

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Improving food security and livelihood conditions of vulnerable rural populations in sub-Saharan Africa has been an on-going challenge. Innovations, suitable to context-specific circumstances of small-scale farmers, are intended to reduce poverty and increase food security. Therefore, it is indispensable to collaboratively identify farmers' views about the factors that influence their action possibilities with regard to the development, adaptation and adoption of innovations. Within the frame of a transdisciplinary research project focused on improving household food security in Tanzania, the aim of this research was to collaboratively assess differences in farmers' expectations, experiences and valuations regarding their innovation outcomes.

Field work took place from January to March 2016 in the Morogoro and Dodoma regions. We present detailed results from two farmer groups that implemented different innovations. A participatory approach guided the use of qualitative tools, including "outcome rating" and "opinion line". These outcome evaluation tools were applied to learn about farmers' perceptions in terms of individuals' valuations and satisfaction regarding their outcomes and to gain insight into what and how different factors, from the farmers' perspective, have influenced these outcomes which were then categorised in terms of different domains of well-being.

The extent in how far farmers' initial expectations matched up with actual outcomes is expressed through farmers' degree of satisfaction, combined with their stated reasons. Interestingly, the individual farmers' valuation of outcomes revealed that their prioritised outcomes were most often related to the "intellectual" domain, which indicates that gaining knowledge was the most important issue for the farmers. Concerning outcomes assigned to the "financial" domain, most farmers were not satisfied with the financial benefits gained through the innovation implementation, which indicates that their financial resources to improve their livelihoods and influence the innovation system remain low. Age and gender were identified as key factors influencing experienced innovation outcomes.

The elucidation of the farmers' perspectives concerning the relevance of certain innovation outcomes and the identification of those that are most important through collaborative evaluation provides important information for potential scaling of the innovation processes. Critically, the results of this study can guide strategies for enhancing social inclusion and pro-poor innovation processes.

**Keywords:** Farmers' valuation and satisfaction, innovation, Trans-SEC

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## Gendered Roles in Yam Cultivation and Food Security in West Africa

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Yam is an important food and cash crop for most families in West Africa. Yam especially has sociocultural significance. It is used in fertility and marriage ceremonies, and many communities across West Africa celebrate yam festivals to mark the end of their harvest season. Nigeria and Ghana are the world's leading producer and exporter of yam respectively. As a consequence of this crucial role the yam sector plays in the two countries, the Community Action for improving farmer-saved Seed Yam (CAY-Seed) project, a Centre for Scientific and Industrial Research (CSIR)-Crops Research Institute (CRI) led project with funding from Bill and Melinda Gates Foundation (BMGF) was initiated. The project sought to improve the quality of small holder farmer saved seed yam and its productivity at community level through positive selection, integrated crop management practices to control viruses and nematodes, and enhance capacity for increased food security and poverty reduction in Ghana and Nigeria. This paper is based on data gathered from surveys and focus group discussions between 2015 and 2016 on the planned intervention. The study finds that there are gendered roles in yam cultivation which are well defined and situated in traditional and patriarchal settings in the two countries. The use of ridges and trellises instead of mounds and single pole staking for instance has eased the previously identified tedious nature of yam production thereby attracting more females to cultivate yam. This has some new implications for ensuring food security especially at the household level. Female farmers mention that the quality and availability of seed yams, cost of inputs, climate variability and availability, quality and cost of land have adverse effects on the potential benefits they can derive from yam production. The paper concludes that the use of new techniques in yam production have the potential to increase the income of female farmers in the long run, empower women, and also promote food security. However, the adverse effects of seed quality, cost of inputs, and land related challenges need to be curtailed.

**Keywords:** Food security, gendered roles, yam cultivation

## Monitoring and Evaluation of Transdisciplinary Food Security Interventions in Kenya

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Monitoring and evaluation of food security interventions of inter- and transdisciplinary research projects is challenging. To relate expected changes on food situation in a given socioeconomic context to these interventions, a proper set of measurement indicators are required. The HORTINLEA project in Kenya supports transdisciplinary research to improve horticultural value chains with a specific focus on rural and urban poor in Kenya. The project measures producer's food security status along the value chain using four indexes: (1) Household Dietary Diversity Score; (2) Food Consumption Score; (3) Adequate Household Food Provisioning and (4) Coping Strategy Index. Despite these indexes have been widely analysed, its applicability in project's context and its relation to the household characteristics needs further research. On the other hand, similar organisations have opted to use household characteristics that demand fewer resources for measurement as proxy indicators of food security. Thus, the objective of this research is to analyse the suitability of different proxy indicators used by HORTINLEA and other organisations in Kenya for measuring food security. Furthermore, it aims at understanding the challenges that existing monitoring and evaluation frameworks face. A mixed-method approach was used, by combining quantitative multivariate analysis for studying household characteristics and the food security scores recorded in the indexes; and a qualitative analysis through thematic research of semi-structured interviews with food security monitoring and evaluation stakeholders. Income, agricultural productivity data and self-qualitative assessment were among the most used proxy indicators of food security. Due lack of resources and difficulties on data recalling and reliability, many organisations have opted to not use the indicators that HORTINLEA is currently using; and those who have been using them, highlight the need of completing the information with other indicators. The multivariate statistical analysis confirmed the suitability of using certain household characteristics as proxy indicators of food security, specially income. The results of this research are expected to contribute to the design of a monitoring and evaluation framework of HORTINLEA and similar projects; as well as to the existing literature on food security measurement.

**Keywords:** Adequate household food, coping strategy index, food consumption score

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# **Animals and food**

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<b>1) Animal husbandry</b>	<b>321</b>
<b>2) Animal nutrition</b>	<b>347</b>
<b>3) Agricultural and food technology</b>	<b>381</b>
<b>4) Agrobiodiversity and nutrition diversity</b>	<b>407</b>

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# Animal husbandry

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## Oral Presentations

- JOHN WAIRORE, STEPHEN MUREITHI, GERT NYBERG, ANJA LINSTÄDTER:  
**Breaking Bad? From Mental Enclosures to Rangeland Enclosures, and *vice versa*** 324
- BULLE HALLO DABASSO, OLIVER WASONGA, PATRICK IRUNGU, BRIGITTE KAUFMANN:  
**Characterizing Stratified Cattle Production as Option for Enhancing Market Outlet for Lean Animals from Pastoral Areas of Kenya** 325
- MARY LUBUNGU, REGINA BIRNER:  
**Using Process Net-Map to Analyse Governance Challenges: A Case Study of Livestock Vaccination Campaigns in Zambia** 326
- CHRISTOPH REIBER, KARIN STOCK DE OLIVERIA SOUZA, SANGEUN BAE, KEBEDE KEFENIE KEFELEGN:  
**Effect of Drought Adaptation Strategies on Goat Performance in NE-Brazil** 327
- KARIN WEDIG:  
**Governing Common Waters: Small-Scale Fisheries and the Growth of Aquaculture on Lake Victoria** 328

## Posters

- GULBAHAR ABDURASULOVA, SARAH ROBINSON, ALBINA MUZAFAROVA:  
**Regional Pasture Network: Knowledge Management and Experience Sharing in Central Asia, China and Mongolia** 329
- LEA LUISE LUDWIG, JUDITH ISELE, GEROLD RAHMANN, ANITA IDEL, CHRISTIAN HÜLSEBUSCH:  
**Forage Biomass Production under Different Stocking Rates and Stocking Densities on a Namibian Livestock Farm** 330
- ANNE SCHUCKNECHT, MICHELE MERONI, FRANCOIS KAYITAKIRE, AMADOU BOUREIMA:  
**Remote Sensing-Based Biomass Estimation to Support Rangeland Management and Food Security in the Sahel** 331

- JOHN-BAPTIST S. N. NAAH, BORIS BRAUN:  
**Assessing Forage Species Diversity, Habitat Distributions, Abundance Trends and Ecological Drivers from Local Agro-Pastoralists' Perspectives in West Africa** 332
- PATRICIA NDUNG'U, OLIVER WASONGA, WILLIAM MNENE, YAZAN ELHADI, OSCAR KOECH:  
**Indigenous Knowledge on Uses, Availability Trends and Variations of Indigenous Grass Species in Southern Kenya** 333
- ELAGBA MOHAMED, AYMAN MUSTAFA:  
**Use of Milk Progesterone Assays for Determining Reproductive Performance in Camel under Farming System** 334
- RAPHAEL ARASIO, BRIGITTE KAUFMANN, DAVID OTIENO, OLIVER WASONGA:  
**Socio-Cultural Foundations and Characteristics of Well-Functioning Pastoral Community Groups in Northern Kenya: The Emic View** 335
- BASOLE OLIVIER KASHONGWE, JOSEPH MATOFARI, BOCK-LINE BEBE, CHRISTIAN HÜLSEBUSCH:  
**Post-Harvest Milk Losses in Smallholder Dairy and Pastoral Camel Herds in Kenya** 336
- EMILY KINSEL, ANTONIA HERM-STAPELBERG, ASTRID BERTELSEN, DANIEL ELLEHAMMER LARSEN:  
**An Analysis of Smallholder Livestock Strategies in the Central Highlands of Kenya** 337
- NYAMIZI BUNDALA, MICHELLE BONATTI, JOYCE KINABO, IZABELA SCHLINDWEIN, CONSTANCE RYBAK, WOLFGANG STUETZ, VICTORIA GOWELE, STEFAN SIEBER:  
**Can Livestock Production Contribute to Consumption of Animal Food Sources? A Case of Rural Tanzania** 338
- BERNDT KRISCHAN RANGE, EVA SCHLECHT, REGINA RÖSSLER:  
**Economic Efficiency of Urban Livestock Production and its Socioeconomic Determinants in Ouagadougou, Burkina Faso** 339
- NHUNG NGUYEN, CUONG TRAN, PHILIPPE LEBAILLY:  
**Comparative Economics and Environment of Shrimp Culture in Buffer Zone of Xuan Thuy National Park** 340
- MUHI EL-DINE HILALI, MOURAD REKIK, BARBARA ANN RISCHKOWSKY:  
**Improved Jameed Processing for Small Scale Sheep Dairy Farms in Jordan** 341

MUAYAD SALMAN, WAEAL HALAWEH, RAWDA ERSHAID, FATHI NAIKAT, HALEMEH STAITEH, WAEAL AL QAISEH, IHAB MALHIS, ALI SHAKHSHEER, MAJDEE AL AGBAR, MOAEN SHTAIEH: <b>Improvement of Sheep Breeds Productivity through Artificial Insemination (AI) in the Jordan Rift Valley</b>	342
MARIA LUISA ESPINEL, SABINE SCHLÜTER: <b>An Approach to Sustainability for Smallholder Dairy Systems Trough Animal Welfare Practices</b>	343
MUHAMMAD DANANG EKO YULIANTO, TRI SATYA MASTUTI WIDI, ESHAN KUSUMAWICITRA, AMIEN FAHRIANTO ADI: <b>Assessment of the Welfare of Racehorses in Central Java, Indonesia</b>	344
ANNA SEIDEL, ADRIAN BOLLIGER, UTA DICKHOEFER: <b>Pen-Fed <i>versus</i> Grazing: The Potential of Forages for Cattle Production in North-Eastern Cambodia</b>	345
ANNA SEIDEL, ADRIAN BOLLIGER, UTA DICKHOEFER: <b>Impact of Forage Management on Yield and Nutritional Quality of Cultivated Forages in North-Eastern Cambodia</b>	346

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## Breaking Bad? From Mental Enclosures to Rangeland Enclosures, and *vice versa*

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Traditional pastoralism is diminishing in some regions today as agro-pastoralists attempt to reconcile their traditional livelihood system with modern influences, progressively adapting to emerging transformations. The results have been an emergence of intensified and diversified agro-pastoralist systems in sub-Saharan Africa (SSA). The emerging agro-pastoralist systems underline a transition, among others characterised by changes in livestock management, production goals and land tenure and use. In line with this transformation, the practice of enclosing land (enclosures and rangeland enclosures) is an increasingly common feature of land tenure and use change, often described as integrated part of land use management today. In East African drylands, we show two ways in which rangeland enclosure has altered pastoral socio-ecological systems (SESSs). The first relates to breaking away from long-held pastoral traditions ('mental enclosures') and embracing emerging transformations such as rangeland enclosures. Such a paradigm shift has eroded the basic tenet upon which sustainable traditional pastoralism is premised while presenting new opportunities for increased flexibility in land use, pasture, livestock management and income generation: opportunities which did not exist before. In highly sensitive climatic regions, defying convention from mental enclosures to rangeland enclosure has also changed the context of adapting to climate change and variability among pastoral communities in the region. The second way traces the peculiarity of the enclosure movement to highlight the incentives and outcomes of this transformation given the prevalence of 'mental enclosures' – land enclosed but not used, claimed but not physically demarcated – in areas where rangeland enclosures predominate.

**Keywords:** Africa, agro-pastoralists, drylands, emerging transformations, enclosure, pastoralism

## Characterizing Stratified Cattle Production as Option for Enhancing Market Outlet for Lean Animals from Pastoral Areas of Kenya

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Economic potential of cattle production in pastoral areas of Kenya is constrained by limited market outlet for lean animals especially during dry seasons. Since the year 1999/2000, when a severe drought was experienced, there has been an emergence of stratified forms of cattle production in which the lean animals are purchased from the pastoral areas for fattening in areas having comparative production advantage. We aim at understanding the characteristics of the stratified forms as option to improve market outlet for the lean animals. Qualitative data was collected using semi-structured questionnaire from purposively selected informants ( $n = 34$ ) in Narok, Taita Taveta and Laikipia areas. Data was coded in the frame of a content-analysis to determine the existing forms of stratified production and their management operations for risks minimisation. We found stratified forms practised on private ranches, leased ranches and smallholder farms, which are undertaken by ranchers, traders, and agro-pastoralists respectively, and differed in their strategy for accessing grazing resources, herd sizes and fattening period. A number of strategies are followed to minimise risks, including purchasing during dry seasons when the livestock prices are low, use of agents to source animals, early sale of slow growing animals and partnership with others. We then, collected data on individual animal weights at purchase, weights at sale, purchase and production costs, for a period of fifteen months from five ranchers ( $n = 683$ ), two traders ( $n = 240$ ) and nine agro-pastoralists ( $n = 140$ ) to determine daily animal weight gains and net revenues per animal (mean  $\pm$  stand error). Daily animal weight gain of  $0.24 \pm 0.1$  kg,  $0.40 \pm 0.0$  kg and  $0.24 \pm 0.0$  kg were observed for ranchers, traders and agro-pastoralists, respectively. Net revenues per animal were  $\$58 \pm 3.0$  for ranchers,  $\$79 \pm 2.9$  for traders and  $\$55 \pm 3.1$  for agro-pastoralists. The study revealed characteristics of stratified forms of cattle production in terms of management operations, animal weight gains and net revenues as potential option to enhance market outlet for the lean animals from pastoral areas of Kenya.

**Keywords:** Drylands, fattening, lean animals, marketing, pastoral areas, profitability

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## Using Process Net-Map to Analyse Governance Challenges: A Case Study of Livestock Vaccination Campaigns in Zambia

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One of the major issues in the implementation of agricultural development projects is how to overcome the implementation problems especially if the provision of funds or inputs such as vaccines is involved. We study a case of a vaccination programme as an example of the more general problems of governance issues that arise during the implementation of agricultural development projects. Vaccination is particularly important because it often is the only way to deal with the livestock diseases, especially in the sub-Saharan African countries. The study employed a novel qualitative research method known as Process Net-Mapping, which is a visual participatory mapping technique to identify, the governance challenges that arise in the implementation process of vaccination programs. Process Net-Mapping involves three main steps. First, the respondents describe the implementation process step by step and identify the actors involved in each step. Second, they rank the influence different actors have on the outcome, and finally, respondents identify the challenges and at what point within the implementation process they occur. The study identified delays in the procurement and disbursement of funds as the main problems encountered in the implementation of vaccinations. The complex design of the procurement procedure results in procurement delays while delays in the release of funds arise because of the diversion of funds. These challenges are not only relevant for vaccination programs, but they are general problems. Therefore, considering e-procurement could address the complexities of the procurement process whereas building a sustainable financial capacity in the overall management of public funds is key in dealing with the challenge of fund diversion. The supply side problems can also be solved through the pressure from the demand side (farmers). However, there is a lack of power from the demand side because there is no much opportunity for interaction between farmers and veterinary personnel due to some social barriers and lack of effective organisation. Lobbying and voting to induce political decision makers to take steps to improve the performance of the veterinary service delivery is one mechanism that farmers can employ to hold the service providers accountable and be able to demand better services.

**Keywords:** Governance challenges, livestock, process net-map, vaccination, Zambia

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## Effect of Drought Adaptation Strategies on Goat Performance in NE-Brazil

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Extensive small ruminant production is an important livelihood strategy for the rural poor in the semi-arid NE Brazil. However, recent studies indicated that frequent droughts along with forage shortage and degradation of the natural Caatinga rangeland were main problems perceived by livestock keepers threatening the sustainability of the farming and eco-systems. Farmers' most frequently suggested drought adaptation strategies were forage production, corralling animals and irrigation. Therefore, this study examined the effect of these drought adaptation strategies on livestock performance parameters such as drought mortality rate, live weight, body condition score (BCS), birth rate, age at slaughter and flock size dynamics of goats. Interviews were conducted with 120 goat farmers. Four systems were distinguished, i.e. goat farms 1. with corralling and irrigation (intensive), 2. with corralling and without irrigation (semi-intensive), 3. without corralling and with irrigation (semi-extensive), and 4. without corralling and irrigation (extensive). Data was analysed using GLM-ANOVA. Results revealed that irrigation systems had significantly larger crop residue and forage areas than systems without irrigation. Semi-extensive systems had largest goat, sheep and cattle herd sizes and largest Caatinga area with lowest feed supplementation levels. Stocking densities were slightly higher in systems with than without corralling, particularly in irrigation projects. With respect to the goat performance indicators, only BCS was influenced by the system with significantly higher BCS (1.8) in intensive systems than semi-intensive systems (1.1) despite of highest feed supplementation levels in the latter system. Goat mortality was slightly ( $p > 0.05$ ) higher in systems without than in those with corralling. Male goats seemed to grow slightly slower in more extensive systems as indicated by higher slaughter ages and lower carcass weights. In summary, intensive systems, particularly those with subsidised irrigation, showed highest goat performance values for which access to forage resources and better control of animals might have contributed. However, based on the multiple-factor approach, we could not reveal a significant effect of adaptation strategies on goat performance.

**Keywords:** Caatinga, drought adaptation, goat husbandry, goat performance

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## Governing Common Waters: Small-Scale Fisheries and the Growth of Aquaculture on Lake Victoria

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Rapid aquaculture growth on Lake Victoria is promising improved food security in the densely populated lake basin and increased exports earnings for Uganda, Kenya and Tanzania, despite declining wild fish stocks. Aquaculture is a highly efficient animal-protein production system, but the expansion of large-scale cage developments frequently creates conflicts over access to fisheries resources with local fishers. High entry barriers to the relatively capital-intensive cage aquaculture for local fishing communities keep transition rates from capture fisheries low. This article assesses the capacities of formal and informal organisational structures that exist throughout the lake basin's fisheries to advance the participation of small-scale fishers and fish-workers in the governance of fisheries resources. Based on a large face-to-face survey and interviews with actor groups in all riparian states, the author examines the capacities of formal co-management institutions, local self-help groups, and fish-farmer associations. Further the scope of the region's national fisheries policies for establishing participatory, multi-level governance structures is evaluated. While Uganda and Kenya pursue rapid aquaculture growth through foreign direct investment, Tanzania is taking a more cautious approach, citing ecological and socioeconomic concerns. All three countries established Beach Management Units (BMUs) for the co-management of fisheries resources, but evidence from our ongoing research shows that BMUs have limited effects on overfishing and potentially intensify existing inequalities by targeting illegal, unregulated and undocumented (IUU) fishing among poor small-scale fishers, while inadequately addressing significant power asymmetries within the fish value chain. New data on informal self-help groups, which are widespread in fishing communities, although often not exclusively focused on fisheries resource management, suggests that grassroots forms of self-organisation can be effective in reducing unequal access to resources in small-scale fisheries and may play an important role in establishing adaptive governance structures. The author argues that integrating informal institutions into co-management approaches could help to avoid poverty-driven social-ecological traps in capture fisheries and improve access to aquaculture for poor fishing communities. Kenya's and Uganda's state support for fish-farmers' associations contributes to inclusive economic development, but so far fails to address the needs of fisherfolks' who are too poor to invest in aquaculture.

**Keywords:** Aquaculture, eastern Africa, inclusive and sustainable development, small-scale fisheries

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## Regional Pasture Network: Knowledge Management and Experience Sharing in Central Asia, China and Mongolia

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Sustainable management of pastures is linked to the ecological and socio-economic stability of Central Asian countries, especially under changing climatic conditions. In the last twenty years, the governance of pasturelands in Central and Inner Asia has transitioned from state-led pasture management to a variety of new tenure systems ranging from private to common property regimes. Although the political context in each country is different, the issues which they face are remarkably similar and include the reconciliation of aims such as wealth creation, provision of access to poorer users, and environmentally sustainable management. Reform processes are constantly evolving – Kyrgyzstan, China, and Tajikistan have implemented various forms of pasture-specific land tenure reform and are still evaluating the results; Turkmenistan and Kazakhstan have launched pasture-specific reforms; Uzbekistan and Mongolia have reformed general land codes and pasture-specific reforms are currently under consideration. These developments have resulted in the accumulation of a vast body of experience and knowledge; the potential benefits of experience sharing have never been greater.

The Regional Pasture Network (RPN) is an innovative and integrated approach for knowledge exchange on sustainable pasture management in Central Asia and Inner Asia (<https://pasture.klink.asia/dms/projects/pasture-network/en>). It was launched in 2016 with the aim to connect policy makers, practitioners and researchers to exchange experiences on pasture management, support the dissemination of these experiences between counties in the region and promote the application of new knowledge in Central Asian states. RPN members benefit from free access to collections of documents in its e-library, regular updates via mailing list, and thematic discussions on the RPN Facebook group. Currently, the RPN is supported by Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ) GmbH, Regional Programme for Sustainable and Climate Sensitive Land Use for Economic Development in Central Asia. It is envisioned to be handed over to a regional organisation in the long run.

**Keywords:** Central Asia, knowledge management, network, pasture management

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## Forage Biomass Production under Different Stocking Rates and Stocking Densities on a Namibian Livestock Farm

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Understanding the effect of variations of stocking rate, stocking density, grazing intensity, grazing itineraries, and durations of grazing and rest events on vegetation responses is crucial for successful rangeland management. Various strategies, i.e. continuous, rotational, deferred, high density, strip, targeted, circuit grazing are advocated, but knowledge on the effects on vegetation and livestock performance is scarce. Grazing management therefore still largely relies on setting average stocking rates to match average carrying capacity, but this concept appears increasingly unsuitable in heterogeneous and variable rangeland environments.

We investigated the impact of increased stocking rate (twice the projected grazing days per paddock) and increased stocking density (strip grazing on a one-or-two-day moving frequency within the projected grazing time) against the current grazing regime (control) on forage biomass production on semiarid 9,500 ha livestock farm Springbockvley in Namibia. Springbockvley is grazed by on average 890 Nguni cattle and 3,700 Damara sheep (grouped in three herds) at an average stocking rate of 41 kg livestock biomass per hectare (established June 2013 - May 2016). The farm is subdivided into 60 paddocks and the three herds graze all paddocks in the same sequence with a resting period of 80 to 100 days between grazing events. The duration of grazing events for each paddock is determined based on visual vegetation assessment at the end of the growing period in May. Destructive biomass sampling was done in May 2014, 2015 and 2016 in 12 test paddocks (3 treatments, 4 replications) within ten single 1 m × 1 m squares along a 200 m transect. Samples were sorted by plant species, weighed, dried and re-weighed. Absolute biomass production varied between treatments and replications, but declined over the monitored period, most likely due to reduced precipitation. However, results on relative biomass production (biomass measured plus biomass hypothetically consumed at the respective stocking rate since the last assessment) indicate that grazing at both, higher stocking density (approx. factor 4) and increased stocking rate (factor 1.2–2) resulted in lower yield depression. Higher density grazing appears to lead to lower accumulation of standing dead plant material and litter. The study is ongoing and data analysis is preliminary.

**Keywords:** Cattle, grazing, ranching, rangeland management, sheep, southern Africa

## Remote Sensing-Based Biomass Estimation to Support Rangeland Management and Food Security in the Sahel

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The livestock sector plays an important economic role in the Sahel and contributes to food security of the people. However, it is highly vulnerable as a result of the large inter-annual variability of precipitation and, hence, rangeland production. This study aims to support effective rangeland management in Niger by developing an approach for mapping rangeland biomass production with remote sensing data. Our linear regression model utilises the phenology-based seasonal cumulative Normalised Difference Vegetation Index (cNDVI), computed from 10-day image composites of the Moderate Resolution Imaging Spectroradiometer (MODIS) NDVI data, as a proxy for biomass production. It is calibrated with ground measurements of herbaceous biomass at the end of the growing season from 2001 to 2015. Different spatial aggregation levels for the model calibration were tested in cross-validation (cv) to find the most suitable one for biomass prediction. In general, the model performance increased with increasing model parameterisation, indicating the importance of additional unobserved and spatially heterogeneous agro-ecological effects (which might relate to grazing, species composition, optical soil properties, etc.). The aggregation scheme, whose calibration units were derived from an unsupervised ISODATA classification utilising 10-day NDVI images from January 2001 to December 2015, showed the best performance with respect to predictive power ( $R^2_{cv} = 0.47$ ) and the cross-validated root-mean-square error (398 kg ha<sup>-1</sup>), although it was not the model with the highest number of calibration units. Once established, the presented approach can be applied for the timely establishment of estimated biomass production maps at the end of the growing season and before field measurements can be made available. This would mean a time gain of two to four weeks, which is the length of time the field trips normally last. Therefore, such maps could be used for the planning of more in-depth field missions, for better management of rangeland resources, and for timely decisions on aid allocation and fire prevention. Additionally, the approach can serve as a backup solution in the event that field surveys are not carried out in a specific year or a specific region.

**Keywords:** Livestock, MODIS, NDVI, Niger, phenology

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## **Assessing Forage Species Diversity, Habitat Distributions, Abundance Trends and Ecological Drivers from Local Agro-Pastoralists' Perspectives in West Africa**

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Studies have shown that land users' local ecological knowledge (LEK) on forage resources is of critical importance for their adaptive rangeland management. Notwithstanding, there has been little discussion on how smallholder farmers perceive forage species diversity, habitat distribution, abundance trends and associated ecological drivers in the management of locally available natural forage resources within West Africa. This study, thus, aims to estimate forage species diversity, analyse habitat types of forage resources, investigate abundance trends of available forage resources, identify local ecological drivers and document conservation measures based on the perceptions of local agro-pastoralists. We used a structured questionnaire to carry out ethnobotanical surveys on their understanding of such ecological variables with respect to forage plants in different parts of northern Ghana and southern-central Burkina Faso. Data were analysed via descriptive statistics, bivariate correlation analysis and cognitive salience index calculation to disentangle the dynamics of local responses to the ecological variables considered in this study. Our results indicated that the local agro-pastoralists exhibited extensive knowledge in forage species diversity, habitat types, abundance trends and ecological drivers. It was also established that local agro-pastoralists associated their cited forage plants more with upland than lowland topography and combined landscapes of the two topographic positions. According to them, approximately 82 % of reported items were considered to be commonly available in local landscapes, while most of them indicated that available forage resources have been experiencing a gradually increasing trend over the past few years. It was also revealed that rainfall variability, tree cutting and drought were the topmost perceived threats causing changes in the trends of forage species abundance. In conclusion, understanding perceptions of local agro-pastoralists regarding above-stated ecological variables could have practical implications in favour of biodiversity conservation.

**Keywords:** Abundance, biodiversity, ecological drivers, forage resources, habitat distribution, rural West Africa

## Indigenous Knowledge on Uses, Availability Trends and Variations of Indigenous Grass Species in Southern Kenya

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Local communities have in the past been invaluable sources of information about their environments and the natural resources that occur within. The inclusion of traditional knowledge alongside scientific research into decision-making processes on natural resource use, particularly of pastures, could improve the adoption rates of proposed policies and technologies thus making our rangelands more productive. To pastoral and agro-pastoral communities that rely on livestock production for 50 % or more of their household income, grass is a key resource. Despite the many uses of the different grass species in Kenya's drylands, their role as livestock feed is the most significant. This study sought to investigate local perceptions on uses, abundance, availability as well as variations of key indigenous grasses in southern Kenya using focus group discussions (FDGs), key informant interviews (KIIs) and a review of previous studies in the study area. Indigenous grass species were found to be mostly used as livestock forage. Their trend in availability and abundance was reported to be both increasing and decreasing with the declining trend mainly being attributed to drought (98 %), increasing human population (82 %), and overgrazing (63 %) while the increasing trend was primarily attributed to the promotion of grass species for the rehabilitation of degraded lands and improvement of natural pasture resources. Interestingly, some important species such as *Panicum maximum* and *Digitaria macroblephara* have rarely been studied for conservation and multiplication purposes despite their reported declining trend. A number of species were identified by the communities in the study site as having ecotypes with different ecological requirements and different preferences by both livestock and the communities. This warrants further studies to screen ecotypes for their biomass yield, nutritional quality and drought tolerance among other factors in order to determine their suitability for arid and semi-arid lands.

**Keywords:** Grass ecotypes, indigenous grasses, local knowledge, southern Kenya

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## Use of Milk Progesterone Assays for Determining Reproductive Performance in Camel under Farming System

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The aim of this study is to use milk progesterone analysis as a new technique to detect the estrus and ovarian activity within four months postpartum in she-camel under farming system. Eight lactating she-camels, eight calves plus one mature male have been selected after calving and divided into two groups (G1 and G2) without male. In (G1) calves were completely restricted from suckling after 60<sup>th</sup> days. Calves of (G2) were freely suckling. Another eight lactating she-camels, eight calves and one mature male were divided into group (GY) which included she-camels in first and second parity, and group (GA) included those in third, fourth and fifth parity. Milk samples were collected from the second week up to the 4<sup>th</sup> month postpartum. Progesterone level was measured by radioimmunoassay (RIA) apparatus. Progesterone concentration fluctuated during the experiment period, and attained higher value of (7.84 ng ml<sup>-1</sup>) in the 8<sup>th</sup> week postpartum in G1 compared to 6.23 ng ml<sup>-1</sup> in the 2<sup>nd</sup> week in G2. Only two she-camel of G1 became pregnant during the first four months postpartum, when progesterone concentration continued to increase from the 12<sup>th</sup> week up to the end of the experiment. Progesterone concentration reached higher level of 8.83 ng ml<sup>-1</sup> in the 6<sup>th</sup> week postpartum of GA compared to 4.7867 ng ml<sup>-1</sup> in 16<sup>th</sup> week of GY. Only one she-camel of GY was suspected to be pregnant due to increased progesterone level from the 12<sup>th</sup> week up to end of experiment. The results revealed that the level of progesterone in milk of she-camel is a good indicator of ovarian activity within the first four months postpartum. Early estrus cycle and regulating fluctuation of milk progesterone of young rather than adult she-camel have been observed. The effect of restricted suckling, parity and age on progesterone concentration was insignificant ( $P > 0.05$ ). More studies are needed using hormonal treatment and new reproductive techniques in camel pastoral system.

**Keywords:** Camel, milk, parity, postpartum, progesterone, reproduction, suckling

## Socio-Cultural Foundations and Characteristics of Well-Functioning Pastoral Community Groups in Northern Kenya: The Emic View

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The socio-cultural context is often ignored when crafting community groups and this has far-reaching effects on their growth and sustainability. Up to now, there is dearth of information about the extent of socio-cultural embeddedness in the way pastoral community groups are organised and governed. This study aimed to assess from an insider's perspective whether such linkages exist and if they have any influence on group performance. The study also sought to assess the social and governance factors that pastoralists perceive as important to the functioning of groups. Information was gathered from participatory likert-type scale rating exercises with 153 income generating groups (IGGs), key informant interviews with 9 head chiefs and officials of 10 IGGs, and semi-structured interviews with 18 IGGs.

The study reveals that pastoralists are drawing from and adapting cultural and social collective practices and norms to new purposes such as income generation. There is a glaring blend between cultural collective activities and the current income generating groups in the way they are organised and governed. Out of the many social factors that are described in literature, only some such as age, gender, education and wealth are considered by pastoralists as important to the functioning of groups. Although these social factors are considered as necessary in the admission of a member to a group, the sufficient criteria lie in the personal character features such as interest and willingness to cooperate such that those with such features are finally admitted. Contrary to the expectation that heterogeneity of social factors may negatively impact on group performance, the converse was found to be true for most factors and reasons for these were well articulated by pastoralists. With regard to governance, pastoralists consider oversight committees, weekly meetings, all-inclusive decision making, by-laws, transparency and accountability related to finances and decision making as fundamental to performance of income generating groups.

Based on these findings, it is important that development efforts to craft or strengthen community groups should take into consideration the socio-cultural dynamics as well as group members' perceptions on the importance of specific social and governance factors if sustainable group activities are aimed for.

**Keywords:** Features, pastoralists, performance, self-help groups, social capital

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## Post-Harvest Milk Losses in Smallholder Dairy and Pastoral Camel Herds in Kenya

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Influence of farm-level practices on milk quality and postharvest milk losses (PHL) were studied using qualitative and quantitative methods in smallholder and pastoral milk producing herds in Kenya. Milk PHL was estimated at 19% in smallholder and at 58% in pastoral herds, and was attributable to milking preparation and milk pooling. *Staphylococcus aureus* was the prevalent mastitis pathogen and was associated with increase in milk somatic cell count. The risk prevalence of *Staph. aureus* was reduced (O.R.: 0.521) for those not washing hands compared to washing hands because sanitisers are not used when washing hands, making the practice ineffective. A reduction in risk of *Staph. aureus* (O.R.: 0.283) was also observed in smallholder herds not suckling calves compared to those suckling, but the risk was lower in pastoral camel herds suckling (O.R.: 0.175) compared to not suckling, suggesting that suckling could help in cleaning the udder prior to milking in pastoral herds where water is scarce. Milking cows in open field in smallholder rural herds had lower risk (O.R.: 0.277) than milking in cowsheds due to reduced accumulation and spread of pathogens. Use of aluminum instead of plastic containers had lower risk of *Staph. aureus* (O.R.: 0.484) in rural farms but it was higher (O.R.: 1.733) in peri-urban because transporters often pool milk from different farms in aluminum containers. The knowledge level of recommended hygienic practices was high in smallholder farms but it was low in pastoral camel herds. Therefore, practicing hand washing with sanitiser and using aluminum containers for milk handling are recommended in smallholder farms, though they should be introduced in a participatory manner for increased uptake. Calf suckling in pastoral camel herds may be recommended due to lack of water for cleaning udders prior to milking.

**Keywords:** Policy implication, postharvest milk losses, *Staphylococcus aureus*

## An Analysis of Smallholder Livestock Strategies in the Central Highlands of Kenya

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This study seeks to investigate the livestock strategies of smallholder farmers in the Central Highlands Region of Kenya. Questionnaire surveys, interviews, and participatory rural appraisal methods were utilised by a multidisciplinary team of students from the University of Copenhagen and the University of Nairobi during fieldwork in Kibugu, Embu County, Kenya. The team found that smallholders in Kibugu depend upon the traditional coffee/tea-cow farming system. Furthermore, farmers prefer to raise exotic cattle breeds, despite their high resource demand and limited suitability to the Kenyan environment. Societal norms dictate a lower social status for farmers who raise small livestock such as poultry and dairy goats. On the other hand, dairy cows, particularly exotic, high producing breeds such as the Friesian, are valued as a reflection of high socioeconomic status. It was also found that government agricultural agencies are ill-equipped to provide effective training in livestock husbandry or entrepreneurship. Unlike other locations in the Central Highlands, Kibugu lacks NGOs promoting less demanding cattle breeds or smaller animals such as dairy goats. Additionally, most farmers lack the financial capital to expand production and take advantage of new market opportunities. Their livelihoods are also influenced by external factors such as land pressure and increasing input prices. Examined within a greater environmental context of increasing climate variability, seasonal unpredictability, and worsening drought, there are indeed many factors that constrain farmers from diversifying their livestock practices. In conclusion, this report recommends that smallholders establish husbandry, breeding, and marketing cooperatives in order to combine their resources and advocate for their interests in the market. Better funded and expanded extension services could encourage innovation and support farmers who aim to diversify production, take risks, and lower the cost burden of inputs. Ultimately, it was determined that holistic approaches to research and development could strengthen farmers' assets and help them adapt to a changing world.

**Keywords:** Dairy cattle, Kenya Central Highlands, livestock strategies, smallholder farming

## Can Livestock Production Contribute to Consumption of Animal Food Sources? A Case of Rural Tanzania

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Inadequate consumption of animal source foods is a common problem in developing countries, including Tanzania. It is linked with persistence of protein and energy malnutrition in the country. This study examined the extent of livestock production and consumption of animal source foods by rural households of Dodoma and Morogoro region, Tanzania. A cross-sectional survey involved 663 households. A questionnaire tool and measurement of food intake were administered to mothers/caregivers in the households. Interviews and focus group discussions were applied to study livestock production and consumption. Data were analysed using SPSS version 20 and Microsoft Excel version 10. Results indicated that cattle were the most important species, kept by the majority of households in Dodoma region while in Morogoro chickens were kept by majority of households. The study revealed a mismatch between livestock production and consumption in both regions. On average more than half (52.4%) of the surveyed households owned livestock, however this was not reflected in consumption of animal source foods. The intake of diets rich in animal sources was low in terms of frequency and quantity for the entire sample. Only 4% consumed milk and its products, 10% consumed meat and 2% consumed eggs. However, of those few who generated and consumed animal products, the dietary diversity was significantly higher compared to their counter parts ( $p = 0.02$ ). Focus group discussion revealed that most households kept livestock as a copying strategy to pay for school fees, medical fees and other necessary household expenditures. Inadequate nutrition knowledge on the importance of including animal source food into the meal, poor livestock keeping practices and lack of diversified agriculture production were found to be among the constraints of consumption of animal source foods. Therefore, empowering rural household members with appropriate knowledge and skills concerning adequate production and consumption of animal source foods will be a key for achieving a good nutrition and health status of rural households.

**Keywords:** Animal source foods, consumption, livestock, production

## Economic Efficiency of Urban Livestock Production and its Socioeconomic Determinants in Ouagadougou, Burkina Faso

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Urban and peri-urban livestock production is considered to be of vital importance to African cities for its contribution to a secure and independent food supply, the generation of income and for strengthening the overall resilience of these human habitats. Despite its high relevance and the ongoing academic discourse, very limited information is available regarding the economic efficiency of this production type at the household level. This study therefore intends to close this research gap by exemplarily assessing the economic efficiency at the producer level of urban livestock production in Ouagadougou, Burkina Faso. Based on the findings, policy decisions and extension strategies can be adjusted and efficient livestock production supported.

The quantitative analyses are based on a combination of two data sets that were collected as part of a baseline survey and during on-farm monitoring of the UrbanFood<sup>Plus</sup> Research Project (GlobE 031A242-A). The baseline survey (n=156), carried out in Ouagadougou in 2014, encompasses data on socioeconomic household characteristics, livestock as well as related costs and revenues. The data corpus is complemented by adding panel data on feed costs (n=1052) from on-farm monitoring of 18 of these households from November 2014 until February 2016. The economic efficiency of urban livestock production is calculated in form of an input-output analysis, which entails all costs and revenues affiliated with the production and sale of cattle, pigs and small ruminants, as well as related animal products. First results indicate that not only the efficiency but also the economic viability of urban livestock production varies considerably among the surveyed households. During the period under review, 23 producers (14.7%) were able to operate profitably, whereas 133 farmers (85.3%) sustained moderate to substantial financial losses. This can primarily be attributed to feed costs, which on average accounted for 86.5% of the total production costs.

The second analytic step of this study involves the estimation of a stochastic frontier production function. This will allow for further insights regarding possible correlations between farm-specific, socioeconomic characteristics and the economic efficiency of livestock production.

**Keywords:** Economic efficiency, livestock production, production function, urban agriculture, UrbanFood<sup>Plus</sup>

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## Comparative Economics and Environment of Shrimp Culture in Buffer Zone of Xuan Thuy National Park

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This paper aims to investigate and compare economic and environmental perspectives of two shrimp systems in Xuan Thuy National Park (Vietnam). The primary data was collected in 2016 through interviewing 30 intensive shrimp farmers and 33 extensive shrimp farmers in the protected area. Economic indicators reveal that the intensive production incurs total costs of  $451 \times 10^6$  Dong ha<sup>-1</sup> which is 18 times higher compared to extensive farming ( $24 \times 10^6$  Dong ha<sup>-1</sup>). Among costs of intensive culture, feeds including pellet feeds, supplements and some antibiotics are the dominant items comprising 58 % ( $260 \times 10^6$  Dong ha<sup>-1</sup>), followed by white leg shrimp spawns and electricity (12 % and 7 % respectively). In the extensive culture, family labour, giant tiger shrimp and crab spawns are the important input costs (respectively 28 % and 27 %). Intensive ponds require huge capital for feeds, hired labour, spawns, electricity, gasoline, sand and lime, while extensive farms use much less pellet feeds, gasoline, lime, and no electricity and sand. Intensive shrimp farming brings higher net profit per hectare of land ( $233 \times 10^6$  Dong) than extensive farms do ( $32 \times 10^6$  Dong). Nevertheless, some economic efficiency indicators illustrate that the return on working capital of extensive farms is 5 times as much as of intensive ones.

From an environmental perspective, extensive shrimp farms apply polyculture which produces diverse aquatic animal products including giant tiger prawns, greasybock shrimps, crabs, miscellaneous fishes and seaweed. This system generally shows more environmental responsibility than monoculture of intensive system. Higher stocking density in intensive shrimp ponds (78.4 heads m<sup>-2</sup>) require more food inputs than extensive farms (7.2 heads m<sup>-2</sup>) and also produce more waste per unit of land. Application of antibiotics and other chemicals in intensive shrimp culture might create more side-effects for shrimps and environment compared to extensive production. The higher frequency in water exchange of intensive shrimp culture might discharge more chemically and biologically contaminated water to the rivers than extensive farms. Based on these insights recommendations for a more sustainable shrimp production in the buffer zone will be developed.

**Keywords:** Economics, environment, shrimp production, Vietnam, Xuan Thuy National Park

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## Improved Jameed Processing for Small Scale Sheep Dairy Farms in Jordan

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Jameed is an important dairy product in Jordan that has been produced in the region for centuries and used as a main ingredient in popular traditional cuisine called Mansaf. Jameed is a hard dry skimmed yogurt, mainly processed using sheep milk in a small scale labor-intensive process. Jameed processing is an important part of the livelihoods of small ruminant keepers and contributes up to 20 % of the households' income.

Evaluation of the traditional processing method and product quality analysis of 90 samples revealed that the traditional processing leads to low churning efficiency and hence fat rancidity problems during storage. The traditional method depends on yogurt churning to separate the butter from the yogurt. The skimmed yogurt (buttermilk) is then transformed into Jameed through a drying process.

A modified processing method was developed and tested at the International Center for Agricultural Research in the Dry Areas (ICARDA) that is based on the use of a milk fat separation technique to obtain skimmed milk that is in turn processed into skimmed yogurt and then dried directly to produce Jameed without the churning process. The eight batches of Jameed produced using this method in small-scale processing units had 73 % less fat and 11 % higher protein content compared to Jameed produced from the traditional method. Further changes in total solids were not significant. Due to the improved fat recovery in the modified method, the ghee yield increased by 29 %. Moreover, the product homogeneity was improved by 60 % with regard to fat and by 25 % in total solids contents. The Jameed colour using the CIELAB indicated that Jameed produced by the modified method was 3.8 % lighter in colour which is preferred by consumers.

A simple cost benefit analysis confirmed that the modified method results in a 60 % saving in energy and water inputs which is a significant benefit in a water-energy-scare country. The expected price premium as a result of improvement in the quality of Jameed is conservatively estimated at 5 %. The combined effect of the cost savings and additional revenue is an increase in net margins (profit) of at least 20 %.

**Keywords:** Dairy processing, dairy product quality, small ruminants

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## Improvement of Sheep Breeds Productivity through Artificial Insemination (AI) in the Jordan Rift Valley

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The project on improved extension for value-added agriculture in the Jordan River Rift Valley was a 3 year project (2011—2014) funded by Japan International Cooperation Agency (JICA), with artificial insemination (AI) as one of the main activities. The implementation of AI programme has been done by a professional team to study the conception rate, twinning rate, lamb birth weight, and 50-day lamb weight of sheep breeds in the Jordan valley. Data was obtained from sheep farms located in three districts (Jericho, Tubas, and Nablus). Variables for conception rate included in the model were location, ewe breed, and parity, and ram breed which was excluded from the model of twinning rate. Furthermore, lamb sex and litter size were added to the model for lamb birth weight and lamb 50 day weight. Among the effects, ewe breed and parity were significant ( $p < 0.05$ ) on conception rate, whereas the locations as well as ram breed were not significant ( $p > 0.05$ ). Twining rate was affected significantly ( $p < 0.05$ ) by location and parity. However, the effect of location, ram breed, litter size, and lamb sex were not significant ( $p > 0.05$ ) on lamb birth weight, while ram breed was the only variable without significant effect ( $p > 0.05$ ) on lamb 50-day weight. Mean of conception rate, twinning rate, birth weight (kg), and 50-day weight (kg) were 62 % (57%-67 %), 1.49 (1.41–1.59), 3.67 (3.51–3.83), and 17.34 (16.43–18.25) respectively. It is concluded that artificial insemination has good results on conception rate and brings positive effects for the twinning rate, thereby contributing to an increase of farm profitability. However, it is important to study the genetic effects of artificial insemination in order to improve traits of economic importance in sheep breeds in Palestine.

**Keywords:** Artificial insemination, conception rate, Jordan Rift Valley, Palestine, sheep breeds

## An Approach to Sustainability for Smallholder Dairy Systems Trough Animal Welfare Practices

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According to the Food and Agriculture Organisation definition, Good Agricultural Practices (GAP) are procedures to obtain agricultural products by pursuing sustainability in the social, environmental and economic aspect. The Good Dairy Practices (GDP) were developed accordingly, with the main objective being sustainable milk production. A main issue for GDP is animal welfare. Animal wellbeing is the result of an adequate physical and mental state of the animal in relation with its environment. Regarding animal health and mental condition, adequate animal welfare has a direct impact on growth, reproduction and production rates, leading to a superior performance. For that reason, to keep animals in high welfare status is the base for efficient, sustainable and profitable dairy farming. Moreover animal welfare practices are a new trend for livestock production. The consumer's preferences for animal products obtained with humane and responsible procedures are a new market demand. The rising awareness for ethical animal handling, sanitary safety and quality of products and environmentally friendly practices are special concerns for consumers, hence they constitute new market pressures for the livestock sector. These aspects challenge smallholder dairy farming, but at the same time open opportunities for products from animals maintained under high welfare standards. On the other hand, the small producers traditional milking practices, low milk yields, adverse environmental conditions, misuse of natural resources and poor infrastructure obstruct good quality and constant milk production. In the case study area of Italva, Rio de Janeiro State, Brazil, we analysed the constraints and potentials to adopt GDP in relation to animal welfare, aiming to support farmers to increase production, achieve higher milk quality, obtain better prices for their product, accomplish sustainability goals and improve their livelihoods.

**Keywords:** Animal welfare, good agricultural practices, smallholder dairy systems, sustainability

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## Assessment of the Welfare of Racehorses in Central Java, Indonesia

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As in many other developing countries, animal welfare issues are not a big topic in Indonesia. The issue is more neglected in livestock which produces foods such as beef cattle, goat, sheep and pig. It is easier to understand the level of welfare in animals which have more direct contact with humans such as companion and working animals, for example horses. This study aimed to assess the level of animal welfare of horses used for racing in Central Java, Indonesia. In the past two decades, equestrian sports such as racing and riding were getting more popular in Indonesia and resulted in an increased number of racing horses. By respecting the five freedoms of animal welfare, we assessed the welfare of 200 heads of racehorses belonging to 13 owners in Central Java. From various sources of literature and assessment of management practices on regular basis, five indicators were selected to describe the five freedoms of animal attributes. Racehorses were individually assessed using those indicators. The assessment was complemented with information on farm level such as feeding, housing and health care management, exercise, training methods, and human-animal interactions. The data were analysed descriptively. The results showed that 60.1 %, 22.9 % and 12.1 % of racehorses had relatively good, moderate, and poor welfare, respectively. In conclusion, most horses used for racing are well handled. Welfare assessment based on objective parameters can be used as first step to improve horse welfare in Indonesia, but needs continuous improvement to improve the horses' life and the racing and equestrian sports itself.

**Keywords:** Five freedoms of animal, Indonesia, racehorse, welfare assessment

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## Pen-Fed versus Grazing: The Potential of Forages for Cattle Production in North-Eastern Cambodia

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Due to conversion of grassland and forest into cropland, rubber and oil palm plantations, smallholder cattle farmers in the Ratanakiri Province, Northeast Cambodia, need to cope with decreasing grazing resources for their animals and with increasing land conflicts. The objective of this study was to evaluate if cultivated forages have the potential to contribute to cattle feeding in order to compensate the loss of grazing areas.

Above-ground biomass yields of cultivated forages (*Brachiaria ruziziensis*, *B. ruziziensis* × *B. decumbens* × *B. brizantha*, *Panicum maximum*, *Paspalum atratum*, *Stylosanthes guianensis*) in Pruok (E 106°96', N 13°57') were determined destructively during the rainy season between June and September 2015. Samples of forages were analysed for their nutrient and energy concentrations. Furthermore, average daily gain (ADG) of cattle pen-fed on cultivated forages (n = 16) was compared with that of animals grazing on native grasslands and in forests (n = 19) on five different smallholdings. Initial bodyweight of the local cattle was 122 ± 33 kg. Pen-fed animals consumed on average 3.9 ± 0.2 kg dry matter (DM) day<sup>-1</sup>. Intake of the grazing cattle was not measured. Live weights were recorded fortnightly for 14 weeks.

Above-ground biomass yields of cultivated forages ranged between 2 and 3 t DM ha<sup>-1</sup> month<sup>-1</sup> with average crude protein, neutral detergent fiber and metabolisable energy concentrations of 84 ± 32 g kg<sup>-1</sup> DM, 647 ± 48 g kg<sup>-1</sup> DM and 7.3 ± 0.4 MJ kg<sup>-1</sup> DM, respectively. The ADG was 79 and 241 g day<sup>-1</sup> in pen-fed and grazing cattle, respectively ( $p < 0.01$ ).

Sufficient forage amounts were supplied to pen-fed cattle, however, the predominant forage was *P. atratum*, a low quality forage. Therefore, the differences in ADG are likely due to variations in nutrient composition between cultivated forages and natural biomass. Under grazing conditions in the rainy season, cattle may select more nutritious biomass. Thus, feeding cultivated forages may not substitute grazing as management practice during the rainy season. However, with decreasing access to grazing land or during the dry season, the use of cultivated forages as an option for pastures or for conservation merits further study.

**Keywords:** Cambodian smallholders, cultivated forages, grazing, productivity

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## Impact of Forage Management on Yield and Nutritional Quality of Cultivated Forages in North-Eastern Cambodia

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Increasing beef prices present smallholders ready to intensify cattle production in the Ratanakiri Province, Northeast Cambodia, with an opportunity to enhance their livelihoods. One intensification approach, which also reduces pressure on increasingly scarce grazing resources, is to cultivate forages on-farm and use these to feed fenced livestock. The objective of this study was to evaluate if weeding and manuring of farm-grown forages have the potential to increase their yield and nutritional quality. Above-ground biomass yields of cultivated forages (*Brachiaria ruziziensis*, *B. ruziziensis* × *B. decumbens* × *B. brizantha* (*B.* hybrid), *Panicum maximum*, *Paspalum atratum*, *Stylosanthes guianensis*) in Lumphat district (E 106°96', N 13°57') were monthly determined destructively during the rainy season between June and September 2015. Forage grasses and *S. guianensis* were cut at  $6 \pm 4$  cm and  $15 \pm 7$  cm above ground level, respectively. Samples of forages ( $n = 41$ ) were analysed for their nutrient concentrations. On 20 smallholdings, forage plots of 0.01 ha were weeded monthly, manured with on average  $0.24 \text{ t N ha}^{-1} \text{ month}^{-1}$ , and compared to 0.01 ha non-managed plots.

Maximum yields were measured in *P. maximum* and *P. atratum* ( $3.6 \pm 1.5 \text{ t dry matter (DM) ha}^{-1} \text{ month}^{-1}$ ), whereas *B. ruziziensis* had the lowest ( $1.1 \pm 0.6 \text{ t DM ha}^{-1} \text{ month}^{-1}$ ;  $p < 0.01$ ). The highest response to management was found in *P. maximum* and *B.* hybrid with an average increase of  $0.8 \text{ t DM ha}^{-1} \text{ month}^{-1}$  compared to non-managed forages ( $p < 0.01$ ). Maximum crude protein concentrations were found in *S. guianensis* ( $128 \pm 8 \text{ g kg}^{-1} \text{ DM}$ ), followed by *B.* hybrid ( $98 \pm 12 \text{ g kg}^{-1} \text{ DM}$ ), *P. atratum* displaying the lowest concentrations ( $65 \pm 8 \text{ g kg}^{-1} \text{ DM}$ ;  $p < 0.01$ ). Neutral detergent fiber concentrations were highest in *B. ruziziensis* ( $668 \pm 16 \text{ g kg}^{-1} \text{ DM}$ ;  $p < 0.01$ ). Managing the forages affected their yields more than their nutritional quality. However, selecting suitably adapted forage species rather than intensifying the management of less well-adapted ones may achieve the yields and nutrition necessary to improve cattle productivity. In this context, *S. guianensis* and *B.* hybrid had the best potential to supplement rations for ruminants.

**Keywords:** Above-ground biomass yields, nutritional quality, smallholders

# Animal nutrition

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## Oral Presentations

- JESSE GAKIGE, CHARLES GACHUIRI, KLAUS BUTTERBACH-BAHL, LUTZ MERBOLD, JOHN GOOPY:  
**Effect of Feeding Sweet Potato Vines Silage on Dry Matter Intake, Milk Yield and Profitability in Smallholder Dairy Systems** 351
- PHILIPP SEIFERT, CHRISTIAN HÜLSEBUSCH, WILBERTH TREJO LIZAMA, EVA SCHLECHT:  
**The Use of Pineapple Husk and Neem Tree Leaves as Anthelmintic Nutraceuticals for Pigs in Mexican Low-Input-Systems** 352
- HYCENTH TIM NDAH, JOHANNES SCHULER, BIRTHE PAUL, BEATUS NZOGELA, WALTER E. MANGESHO, RICHARD MOLLEL, ROSE LOINA, VENANCE KENGWA:  
**Factors Affecting the Adoption of Forage Technologies under Smallholder Dairy Production Systems in Tanzania** 353
- O. MOSES ARIGBEDE, AYOTUNDE OLUSEUN OGUNSAKIN, ADEKUNLE OLUYEMI AKINLOLU, ADEBAYO ONI, KARL-HEINZ SÜDEKUM:  
**Graded *Enterolobium cyclocarpum* Seed Meal in Total Mixed Rations for West African Dwarf Rams** 354
- PHILIPP STRAUB, ISAAC OSUGA, CHRYSANTUS MBI TANGA, WILHELM WINDISCH, SEVGAN SUBRAMANIAN:  
**Development of a Semi-Synthetic Diet for Mass Production of the Edible Desert Locust *Schistocerca gregaria* Forskål (Orthoptera: Acrididae)** 355

## Posters

- ELENA NARCISA POGURSCHI, MONICA PAULA MARIN, CARMEN GEORGETA NICOLAE, MARIUS MAFTEI, MELANIA FLORINA MUNTEANU, DANA CATALINA POPA, CORINA-AURELIA ZUGRAVU:  
**Nutritional Characteristics and Quality of Eggs from Laying Hens Fed Diets Supplemented with Different Oils Produced in Romania** 356

- MOHAMED AHMED, MAZEN ALI, OMAR SALLAM:  
**Response of two Broiler Strains to Different Dietary Levels of Vitamin C During Summer** 357
- MOHAMED MOMANI SHAKER, NAFEZ A. AL-BEITAWI, ZIYAD BEN MAHMOUD:  
**The Effect of Sea Buckthorn (*Hippophae rhamnoides* L.) Fruit Residues on Performance and Egg Quality of Laying Hens** 358
- CHRISTIAN LÜCKSTÄDT:  
**Impact of Dietary Sodium Diformate on Layer Performance and Health under Farm Conditions in Nigeria** 359
- ISAAC OSAKWE, BRIDGET NWACHUKWU, IFEOMA NNAMANI:  
**Performance and Haematology of Broiler Starter Birds Fed Graded Levels of *Gongronema latifolium* (Utazi) Leaf Extract** 360
- K. D. AFOLABI, A.H. EKEOCHA, O. I. ADEYOSOYE, F.A. BELLO:  
**The Performance, Haematology, and Economy of Broilers Fed Diets with Cayenne Pepper (*Capsicum annum*) Meal** 361
- KHATERINE SALAZAR-CUBILLAS, PEDRO SAINZ-SANCHEZ, RAVINDRAVARMA GOWNIPURAM, SEBASTIAN GLOWACKI, SHIMELS WASSIE, ALICE ONYANGO, JOAQUÍN CASTRO-MONTOYA, UTA DICKHOEFER:  
**Protein Nutrition of Dairy Cows in the Tropics: Challenges and Perspectives** 362
- RISMA RIZKIA NURDIANTI, KARL-HEINZ SÜDEKUM, CHRISTIAN BÖTTGER:  
***In vitro* Rumen Fermentation of *Sauropus androgynus* (L.) Merr. Compared to Hays of Different Quality** 363
- MAURICIO EFREN SOTELO CABRERA, JHON F. GUTIERREZ SOLIS, MICHAEL PETERS, BELISARIO HINCAPIE, STEFAN BURKART:  
**Cattle Production under Grazing with Improved Forages in the Lowland Tropics of Colombia** 364
- RAÚL RIVERA, JORGE VARGAS, CARLOS A. GOMEZ, KHATERINE SALAZAR-CUBILLAS:  
**Increasing Milk Production Using Dormant Alfalfa (*Medicago sativa* L.) in the Peruvian High Plain (Puno)** 365
- THALYANE RODRIGUES, CAROLINE MEDEIROS SOUZA, EDUARDO MICHELON NASCIMENTO, HELOISE MAGGIONI, CARINE INÊS SCHRÖTER BACH, WILLIAN GONÇALVES NASCIMENTO, SERGIO RODRIGO FERNANDES, AMÉRICO FRÓES GARCEZ NETO:  
**Diet Selection and Ingestive Behaviour of Lambs Fed Diets with Increasing Levels of Whey Permeate** 366

- JULIAN PLAGEMANN, SERGE EUGÈNE MPOUAM, REGINA RÖSSLER, EVA SCHLECHT:  
**Feeding of Dairy Cows, Beef Cattle and Pigs in Peri-/Urban Agriculture in Ouagadougou, Burkina Faso** 367
- ASEP INDRA MUNAWAR ALI, SHIMELS WASSIE, DANIEL KORIR, JOHN GOOPY, LUTZ MERBOLD, KLAUS BUTTERBACH-BAHL, UTA DICKHOEFER, EVA SCHLECHT:  
**Effect of Sweet Potato Vine Silage and Urea Molasses Supplementation on Feed Intake, Diet Digestibility and Methane Emissions of Heifers on a Poor Quality Tropical Diet** 368
- SHIMELS WASSIE, ASEP INDRA MUNAWAR ALI, DANIEL KORIR, JOHN GOOPY, KLAUS BUTTERBACH-BAHL, LUTZ MERBOLD, EVA SCHLECHT, UTA DICKHOEFER:  
**Effect of Sweet Potato Vine Silage and Urea-Molasses Blocks on Nutrient Intake, Nitrogen Balance and Rumen Microbial Protein Synthesis of Crossbred Heifers on a Poor Quality Diet** 369
- SAEED MURTAZA, ABDUL SATTAR, NASIM AHMAD, IJAZ AHMAD, IRFANUR REHMAN, REHANA KOUSAR, MUHAMMAD SHAHZAD:  
**Effect of Exogenous Administration of Oxytocin on Follicular Dynamics and Milk Contents in Partially Lactating Nilli-Ravi Buffaloes** 370
- BASSEY HARRY, AUSAJI AYUK, MAGNUS ANYA:  
**Performance of Weaned Rabbit Bucks Fed Graded Levels of African Yambean in Cassava Peel Meal-Based Diets** 371
- BEN LUKUYU, FRED KABI, AUDERY BYARUGABA, JANE KUGONZA, RONALD WABWIRE, GIDEON NADIOPE:  
**The Constraints and Opportunities in the Compounded Feed Production and Supply Chain in Uganda** 372
- TITIS APDINI, JAN DIJKSTRA, DANIEL RIBEIRO MENEZES, ALINE DA SILVA SANTANA, PATRÍCIA RODRIGES DE LIMA, AMÉRICO FRÓES GARCEZ NETO:  
**Effect of Tannin and Soybean Oil Supplementation on Gas Production, Degradability and Ruminant Fermentation** 373
- PHYLLIS NDUNG'U, BOCKLINE BEBE, JAMES ONDIEK, KLAUS BUTTERBACH-BAHL, LUTZ MERBOLD, JOHN GOOPY:  
**Improved Region-Specific Emission Factors for Enteric Methane Emissions from Cattle in Nandi County, Kenya** 374
- DANIEL KORIR, CHARLES GACHUIRI, KLAUS BUTTERBACH-BAHL, LUTZ MERBOLD, JOHN GOOPY:  
**Digestibility, Energy Use Efficiency and Methane Production in Steers Fed at Restricted Levels of Intake** 375

- ERNEST DARKWAH YEBOAH, YU-GUO ZHEN, CHARLES ADARKWAH:  
**The Immuno-Nutritional Effects of Dietary *Astragalus* Polysaccharides on Weaned Pigs under Smallholder Conditions** 376
- BUKE DABASSO, ANSELIMO MAKOKHA, HASSAN ROBA, ARNOLD ONYANGO:  
**Chemical and Nutritional Characteristics of Traditional Meat Products of Borana Community in Marsabit County, Kenya** 377
- OLAYEMI OLUGOSI, J. OLUWASOLA AGBEDE, MUYIWA ADEGBENRO:  
**Detheobromination and Improvement of Nutritional Quality of Cocoa Pod Husk through Solid State Fermentation Using *Rhizopus stolonifer*** 378
- SAOWALUCK YAMMUEN-ART, AUDTAKORN SUTARMJAM, APICHART SEEPAI:  
**Fermentation Quality and Chemical Composition of Napier Pakchong 1 Silage Supplemented with Lactic Acid Bacteria** 379
-

## Effect of Feeding Sweet Potato Vines Silage on Dry Matter Intake, Milk Yield and Profitability in Smallholder Dairy Systems

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Smallholder dairy production is a key economic activity in Kenya, responsible for the improvement of nutrition and livelihoods of many. Tropical (C4) grasses and stovers, which frequently form the bulk of cattle's diets have poorer digestibilities, lower energy and less protein than is required to sustain milk production and smallholders frequently purchase commercial dairy meal (CDM – a grain-based concentrate) to supplement their animals' diets and so lift production. A less expensive alternative to CDM would have immediate, positive effects on profitability and household income. A feeding trial was conducted to evaluate the effect of feeding sweet potato vines silage as an alternative to CDM on productivity of lactating dairy cows. Fourteen Friesian cows in late lactation fed a basal diet of Napier grass, were supplemented with either CDM or sweet potato vines silage mixed with wheat bran (SPVS). Milk production, feed intake, live weight (LW) change and income per liter of milk were monitored for a period of 56 days. Milk production for CDM was greater than for SPVS ( $7.61 \text{ day}^{-1}$  vs  $6.25 \text{ day}^{-1}$ ;  $p < 0.05$ ). Cows on CDM had a higher dry matter intake than those on SPVS ( $9.01$  and  $7.78 \text{ kg DM d}^{-1}$  respectively;  $p < 0.05$ ). LW change per week was not different between the two treatments. Gross margin per liter of milk was greater for SPVS than CDM ( $11.72$  vs  $0.26$  Kenyan Shilling  $\text{L}^{-1}$ ;  $p < 0.05$ ). Our results showed clearly, that while supplementation with SPVS supports a lower level of production than CDM, its much lower cost means that sweet potato vine silage mixed with wheat bran is a viable and financially attractive alternative to commercial dairy concentrate and is suitable for adoption by smallholder farmers.

**Keywords:** Late-lactation, silage, sweet potato vines



## The Use of Pineapple Husk and Neem Tree Leaves as Anthelmintic Nutraceuticals for Pigs in Mexican Low-Input-Systems

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The creole pig is an important source of protein in traditional farming systems in Yucatán, México. Gastrointestinal helminthiasis causes considerable economic losses due to retarded animal growth and lowered feed conversion efficiency. Pineapple husk (*Ananas comosus*) and neem tree leaves (*Azadirachta indica*) are widely available in tropical countries and are used against gastrointestinal parasites in ruminants. Yet, their effectiveness against pig helminths has to date not been studied.

A trial was conducted at the experimental stables of *Universidad Autónoma de Yucatán*, México. It included 29 young creole pigs of  $9.6\text{ kg} \pm 2.9$  liveweight with natural polyparasitic infections exceeding a threshold value of 200 eggs per gram of feces (EpG). Animals were randomly assigned to treatment group A (ananas, n=9), treatment group N (neem, n=10) and control group C (n=10). Mixed infections including *Strongyloides* spp., *Oesophagostomum dentatum* and *Trichuris suis* were detected using the modified McMaster test. Main components of the experimental diets administered for 10 days were 65 % maize- and 15 % soybean-meal. They further contained 17 % dried pineapple husk (group A) and 15 % dried Neem leaves (group N) at uniform crude fiber concentrations across treatments. During the experiment, individual EpG values were determined every 48 hours. On day 10, 6 animals per treatment were killed and parasites remaining in the digesta of the gastrointestinal tract (GIT) were identified and counted (cpGIT). EpG and cpGIT in control animals were compared to values in treated animals for computation of treatment percentage efficacy (TPE).

In group N, no significant EpG-changes could be found (TPE: +3 %,  $p > 0.10$ ) after 10 days, whereas EpG was decreased by 84 % (TPE) in group A. Necropsy and cpGIT showed an increased cpGIT (+31.2 % TPE) in group A and suggested a slight reduction of adult female parasites in neem treated animals (TPE: -15.3 %,  $p \geq 0.05$ ). Body weight change and hematocrit did not show significant differences ( $p > 0.10$ ) neither between nor within the groups.

Our findings suggest that pineapple husk is a nutraceutical that may reduce fecundity and hamper oviposition in swine-pathogen helminths. Further research is needed to confirm these findings and to specifically investigate the mode of action of pineapple husk.

**Keywords:** Ethnoveterinary medicine, helminths, nutraceutical, pigs, pineapple

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## Factors Affecting the Adoption of Forage Technologies under Smallholder Dairy Production Systems in Tanzania

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For over fifty years, researchers have tested and introduced forage technologies aiming at improving cattle's productivity in sub-Saharan Africa (SSA). In spite the potential positive impact of improved forage varieties (IFV) on milk yields, its adoption by smallholder livestock farmers in SSA has remained unsatisfactory. Our study aimed at identifying opportunities and constraints for the adoption of IFVs in smallholder dairy production systems in SSA with a special focus on Lushoto, Tanzania. It is based on a literature review, a range of empirical social research methods alongside the application of a Qualitative Assessment Tool for Forage Technology (QATo-FT) in a multi-stakeholder learning workshop.

The most important findings for a limited adoption of IFV centred on the lack of knowledge on the stabilising effect of forage production on milk yields, the low value of labour in the dry season resulting in farmers engaging in labour intensive, long-distance cut-and-carry feeding, as well as limited access to existing dairy markets creating a bottleneck between producers and consumers.

In order to offset these challenges, the following recommendations for a wide scale adoption and up scaling of IFVs were derived: 1) Knowledge transfer on the benefits of IFVs, their proper management (establishing, maintenance, timing of harvesting), conservation and optimal utilisation in livestock is needed, using participatory approaches and mass media. 2) Local and regional administration can help to strengthen partnerships between involved stakeholders such as farmers, NGOs, service providers, extension officers and other networks beyond the existing village innovation platforms. 3) Increasing the value of labour through off-farm income possibilities will make IFV a necessary, labour-saving activity. 4) Creating better access to existing markets (e.g. through establishing better connections to local collection centres) would generate an incentive for planting IFV, supporting a higher milk production.

The aforementioned actions hold the key to motivate small-scale dairy farmers' uptake of productive farm actions such as improved forage technologies. As a result, the performance of existing heads of cattle would improve, milk yields would increase and farmers' income levels could be enhanced, helping to reduce poverty in the region.

**Keywords:** Adoption constraints, forage technologies, livelihoods, livestock systems

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## Graded *Enterolobium cyclocarpum* Seed Meal in Total Mixed Rations for West African Dwarf Rams

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Globally, urbanisation has resulted into dwindling grazing lands, and this calls for agricultural practices that will be less dependent on large expanse of land. Apart from foliage, seeds from multi-purpose tree species are potential sources of nutrients for ruminant animals. Thus, they can be included in rations to improve intake and performance of intensively managed animals and serve as source of year-round cheap feed. This study was carried out to determine the intake and performance of West African Dwarf Rams fed graded levels of toasted *Enterolobium cyclocarpum* (Jacq. Griseb) seed meal (TECSM) in total mixed rations (TMR) Five diets were formulated to contain TECSM at 0 (control), 10, 20, 30 and 40 % inclusion levels using 25 rams averaging  $11.40 \pm 0.20$  kg and aged 10–12 months. In a completely randomised design, the rams were assigned to 5 treatment groups of 5 rams each, housed in individual pens and fed their respective diet over 16 weeks. Data collected included dry matter and nutrients intake, weight gain, nutrient digestibilities, nitrogen utilisation, feed conversion ratio, feed efficiency and haematological indices. Rams fed TECSM had higher dry matter intakes than those fed the control diet while those fed at 20 and 30 % levels had higher crude protein intakes. Rams fed 0 % TECSM had higher neutral detergent fiber, acid detergent fiber, lignin and hemicellulose intakes (289, 172, 80 and  $110 \text{ g d}^{-1}$ ). Nutrient digestibilities were significantly higher ( $p < 0.05$ ) in rams fed TECSM at 30 and 40 % levels than others but the two treatments were similar. Rams fed 30 % TECSM had improved ( $p < 0.05$ ) feed conversion ratio and feed efficiency. The glucose level was highest in the blood of rams fed 30 % TECSM ( $112 \text{ mg dl}^{-1}$ ), but total protein, albumin, globulin and cholesterol levels were similar ( $p > 0.05$ ) in all the treatments. Incorporating TECSM in TMR is a promising feeding strategy especially during the dry season when there is scarcity of high quality forages and when grazing resources are limited. It is recommended that TECSM could be used as a plant protein source in TMR for small ruminants up to 30 % inclusion level for optimum performance.

**Keywords:** Digestibility, haematology, nitrogen utilisation, performance, voluntary intake

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## Development of a Semi-Synthetic Diet for Mass Production of the Edible Desert Locust *Schistocerca gregaria* Forskål (Orthoptera: Acrididae)

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Due to a fast-growing world population, demand for food, especially high quality protein is increasing drastically. Insects as human food and feed supplements for animals is emerging as a potential option. Desert locust, *Schistocerca gregaria* Forskål is one among the edible insects considered. Currently communities consume desert locusts when they swarm. Mass-rearing protocols for desert locust under laboratory conditions, based on natural or half-synthetic diets such as wheat seedlings or fresh grass are widely available. However this requires constant supply of these substrates which makes the systems more sensitive to fluctuations. Hence there is a need to standardise alternative, storable food substrates that are readily available. In this regard, the effects of different, dried and therefore storable feeding substrates on growth and development of the desert locust was assessed. Five different formulations of feeding substrates were used in the study: Feed A: cornmeal + cowpea leaf powder (50:50); Feed B: corn stover powder + soybean powder (50:50); Feed C: cornmeal + cowpea leaf powder + carrot powder (40:40:20), supplemented with multivitamins; Feed D: corn stover powder + soybean powder + carrot powder (40:40:20), supplemented with multivitamins; Feed E: cowpea leaf powder + soybean powder + carrot powder (40:40:20), supplemented with multivitamins. Increase in biomass of locust was monitored at 3-day intervals. Although all animals started to feed on all diets, diet B ended up in complete mortality until day 14. With diet C only a few animals survived until the end of the study with low individual weight gain. Diet A resulted in good individual body weight gain, however associated with high varying survival rates, up to complete mortality within individual cages. Diet D and E performed well with diet D being superior compared to all other diets regarding feed consumption, individual body weight gain, development rate and survival rate. Hence, a protein rich diet comprising of soybean and cowpea leaf powder, supplemented with carrot powder and a source of multivitamins proved to be an effective storable food substrate for locust rearing. We anticipate that these findings will lead to further efforts to refining mass rearing protocols for locust.

**Keywords:** Feeding substrates, locusts, nutrition

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## Nutritional Characteristics and Quality of Eggs from Laying Hens Fed Diets Supplemented with Different Oils Produced in Romania

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By the present work, we proposed to assess the nutritional characteristics and quality of eggs from laying hens fed diets supplemented with different types of oils produced and marketed in our country, oils with low price, respectively soya bean oil, sunflower oil and rapeseed oil. The study was performed with 729 laying hens 33 week-old belonging to ROSO/SL/2000 hybrid. The hens were allotted to 3 groups, each group received isonitrogenous diets for a period of 10 weeks. Experimental diets were included: 1) 7.74 % soya bean oil, 2) 7.92 % sunflower oil, 3) 7.83 % rapeseed oil. The energy content of diets were: 1) 11.69 MJ ME/kg, 2) 11.85 MJ ME/kg, 3) 11.67 MJ ME/kg, whereby these differences were supposed to not influence the expected results. Egg weight, fatty acid composition of yolk, polyunsaturated fatty acids n-3, n-6 and their ratio were determined. The inclusion of soya bean oil, sunflower oil and rapeseed oil in the diet of laying hens had no significant effect on egg weight. The fatty acids profiles of yolk were affected by experimental diets. The sunflower oil and soya bean oil increased linoleic acid content in egg yolk. The higher level of omega-3 polyunsaturated fatty acids in egg yolk was observed in laying hens which received soya bean oil in their diet. The omega-6 polyunsaturated fatty acids of egg yolk significantly decreased for laying hens which received rapeseed oil ( $p < 0.05$ ). It was found that the soya bean oil group had higher ratio of unsaturated to saturated fatty acids compared to other groups. Lower ratios of n-6 to n-3 fatty acids were also found in the egg yolk of the soya bean oil group. Taken together, these results suggest that egg weight is not affected by the presented oil sources, whereas fatty acid contents and profiles are directly affected.

**Keywords:** Egg yolk, laying hens, Romanian oils, unsaturated fatty acids

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## Response of two Broiler Strains to Different Dietary Levels of Vitamin C During Summer

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This experiment was conducted to investigate the responses of two broiler strains Ross 308 and Cobb 500 to 4 levels of vitamin C (0, 150, 200 and 250 mg per 1 kg feed). One hundred and twenty one-day-old chicks of each strain were used in this study. The experiment was extended for 6 weeks, during which starter feeds were fed for the first 3 weeks and finisher feeds were given there after. The experiment was conducted in an open-sided house at Khanfar area, Abyan district (Yemen). Birds were randomly assigned to the treatments with 3 replicates of 10 birds each. Weekly body weight, feed intake, body weight gain, feed conversion ratio (FCR), production yield  $\text{kg m}^{-2}$  and carcass characteristics were recorded. In addition some physiological parameters (body temperature, red blood cells and hemoglobin), heterophil, lymphocyte, lymphocyte heterophil ratio, serum protein, serum uric acid, serum glucose and serum cholesterol were also studied. A split-plot design was used in which 2 main plots (strains) were fed the 4 levels of vitamin C as sub-plots. Data were analysed by the general linear model (GLM) procedure; Duncan's multiple range test was used to compare the treatment means. The results revealed that Cobb 500 was significantly ( $p \leq 0.05$ ) superior to Ross 308 in terms of body weight, feed intake, body weight gain, FCR and dressing percentage. However, Ross 308 showed significantly ( $p \leq 0.05$ ) higher relative weights of heart, liver and gizzard than Cobb 500. With the increasing levels of vitamin C, live body weight, FCR, livability and production yield were significantly ( $p \leq 0.05$ ) improved. Moreover, feed intake was numerically increased at 250 versus 0 mg vitamin C. Strain had no significant ( $p > 0.05$ ) effect on body temperature. Nevertheless, supplementation with 200 mg vitamin C/kg feed significantly ( $p \leq 0.05$ ) reduced body temperature compared to 0 and 250 levels. Supplementation with different levels of vitamin C significantly ( $p \leq 0.05$ ) increased serum protein compared to unsupplemented chicken. Serum uric acid was significantly ( $p \leq 0.05$ ) reduced at 200 and 250 mg vitamin C versus control.

**Keywords:** Broiler performance, carcass, physiology, strain, vitamin C

## The Effect of Sea Buckthorn (*Hippophae rhamnoides* L.) Fruit Residues on Performance and Egg Quality of Laying Hens

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This experiment was conducted at the ITP (International Testing of Poultry) in Ústřasice, Czech Republic. 1440 eighteen weeks old pullets Isa Brown were divided into two groups of 720 hens and each of them had 24 subgroups (30 hens each). The aim of this experiment was to study the effects of sea buckthorn fruit residues on hen performance and quality of eggs. The experimental group was fed diets in which 5 % of the wheat was replaced by sea buckthorn fruit residues. The control group was fed diets without any colour additives. Egg production and intensity of laying hens were evaluated in seven periods, from 127 to 322 days of age. In our study significant effects ( $p \leq 0.05$ ) of sea buckthorn fruit residues on total number of laid eggs and egg yolk colour were detected. However, no effect of sea buckthorn was found on hen performance or egg quality including egg weight, yolk weight, eggshell strength, shape index of egg, eggshell thickness, Haugh units, eggshell colour, blood spot, and albumen weight proportion.

Results of our study suggest that the replacement of 5 % of the feed wheat with sea buckthorn fruit residues significantly increases the total number of laid eggs as well as the egg yolk colour (being darker), which is favoured by consumers. The other qualitative characteristics of eggs and of performance did not differ. However, further studies on the effect of sea buckthorn are needed.

**Keywords:** Egg quality, laying hens, sea buckthorn

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## Impact of Dietary Sodium Diformate on Layer Performance and Health under Farm Conditions in Nigeria

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Microbiological integrity of eggs is an important issue, while bacterial pathogens in feed and environment of layer units can have serious consequences for bird health and productivity, especially in tropical regions, where higher environmental temperatures and humidity allow pathogens to thrive. Organic acids have long been used in animal nutrition to stabilise feed and enhance animal performance. Early studies on these additives were carried out in pig production; however they have been increasingly adopted in the layer industry since the early 1990's. Sodium diformate (NDF) has been widely used in poultry production in tropical areas since 2009. However, its impact under layer production systems in Africa was yet to be thoroughly investigated. This formed the impetus for the current study — a commercial trial in Nigeria. Here, the impact of 0.3 % dietary NDF on performance and health in laying hens from 55 weeks of age was studied over a period of eight weeks. The treatment and control groups (1050 birds per group) each received a commercial layer diet throughout the trial. Feed intake over the trial period was lower in the birds that received the NDF diet (119 v. 122 g per bird and day;  $p < 0.001$ ), while hen day egg production improved over the same period (85.9 v. 77.7 % in NDF and control groups, respectively;  $p < 0.001$ ). The average number of eggs laid over the experimental period was 57,518 in the group given the NDF diet, compared to only 51,047 in the control group ( $p < 0.001$ ). At the end of the trial, total egg weight was 3510 kg in the NDF group, compared to 2910 kg in the controls, although due to the collection method, no statistical comparison was possible. Finally, the use of the additive led to reduced mortality (0.7 v. 3.8 % in the NDF and control groups, respectively;  $p < 0.001$ ). These data show that sodium diformate (traded as Formi NDF) is able to improve performance and survival rates in layers under commercial tropical conditions in Nigeria and may thus be a viable alternative for antibiotic inclusion in feed.

**Keywords:** Dietary sodium diformate, layers, Nigeria, organic acids



## Performance and Haematology of Broiler Starter Birds Fed Graded Levels of *Gongronema latifolium* (Utazi) Leaf Extract

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The use of ethno-pharmacological plants as growth promoters in livestock has become necessary as a result of the problems of resistant strains and residue from antibiotic growth promoters. *Gongronema latifolium* has shown both bacteriocidal and bacteriostatic effects on microorganisms and this has necessitated the intention to investigate the effect of *G. latifolium* extract on growth performance and haematology of broiler birds. Ninety six Agrited day-old broiler chicks were randomly assigned to four treatment groups of 24 birds, each replicated three times with 8 birds per replicate in a completely randomised design. The groups were fed four diets. Diet 1 (T1) contained no *G. latifolium* and served as the control. Diets 2, 3 and 4 (designated T2, T3 and T4, respectively) contained 10 ml, 20 ml and 30 ml, respectively of *G. latifolium* extract. The extract was produced by dissolving 100 g of the dried and milled *G. latifolium* leaf in one litre of water. Thereafter 10 ml, 20 ml, and 30 ml, respectively, were decanted and dissolved in one litre of water for the various treatments. Feed and water were offered *ad-libitum* and data were collected on growth and haematological indices. Results showed that there were significant ( $p < 0.05$ ) differences in weight gain and feed intake and no difference ( $p > 0.05$ ) in haematological parameters. Birds fed T2 (10 ml) and T4 (30 ml) gained more ( $p < 0.05$ ) weight ( $29.8 \text{ g d}^{-1}$ ) and ( $29.2 \text{ g d}^{-1}$ ), respectively than birds on the control diet ( $27.4 \text{ g d}^{-1}$ ). Similarly, birds fed T4 consumed more ( $p < 0.05$ ) feed ( $54.4 \text{ g d}^{-1}$ ) than birds on the control and T2 diets ( $47.7 \text{ g d}^{-1}$ ) and ( $50.9 \text{ g d}^{-1}$ ), respectively. There were no significant ( $p > 0.05$ ) differences in feed conversion ratio, water intake and blood parameters measured. These results showed that 10 ml extract of *G. latifolium* enhanced growth performance of broiler starter birds without any adverse effects on their blood chemistry.

**Keywords:** Broiler starter, *Gongronema latifolium*, growth, hematology

## The Performance, Haematology, and Economy of Broilers Fed Diets with Cayenne Pepper (*Capsicum annuum*) Meal

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Pepper, organic in nature, has been used as spice, seed preservative and a rural remedy against livestock diseases and parasites. The effect of dietary Dried Cayenne Pepper-DCP (*Capsicum annuum*) meal on the performance, haematology, and carcass traits of broilers fed in three phases were evaluated. In a completely randomised experiment, 240 day-old broiler chicks were allotted to 4 experimental diets at the pre-starter (0 – 3<sup>rd</sup> weeks), starter (4 – 6<sup>th</sup> weeks) and finisher (7 week) phase for 7 weeks. Animals were kept in a deep litter poultry house at 20 chicks per replicate of three. Four experimental diets were formulated for each of the growth phases with 0.1, 0.2 and 0.3 % DCP meal in diets 2, 3 and 4, respectively, while diet 1 without DCP meal served as the control. Inclusion of DCP meal at 0.1 – 0.3 % level in broilers diet improved their feed intake, weight gain, and efficiency of feed utilisation over birds fed no DCP. Although the cost of feed, and total cost of feed intake per bird were increased, the gross revenue, gross margin and relative gross margin were also increased in birds fed diets with DCP meal. Optimal performance and economy of production were obtained for broilers fed diets with 0.3 % DCP meal, where the significantly highest values were obtained for weight gain, final body weight and feed efficiency. Also the highest value for gross revenue (Naira 1869.00), gross margin (Naira 1343.60) and relative gross margin (1.15) were obtained for broilers fed 0.3 % DCP. The haemoglobin (9.57 – 11.60 g dl<sup>-1</sup>) and mean cell hemoglobin concentration (26.91 – 32.31 %) values were similar across diets. The blood leukocytes and platelets of broilers fed diets with DCP meal were significantly elevated over the control. Broilers' carcass cut and internal organs weights were not adversely affected by DCP meal. Inclusion of up to 0.3 % dried cayenne pepper meal in broilers' diet improved their performance at a low cost had no adverse effect on their carcass traits and haematology but elevated the platelets and the leucocytes cell count as a potential blood clotting and immunity booster.

**Keywords:** Broiler, carcass quality, cayenne pepper (*Capsicum annuum*), haematology, performance

## Protein Nutrition of Dairy Cows in the Tropics: Challenges and Perspectives

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Global milk demand is estimated to grow by 25 % over the next 10 years, in particular in tropical regions of Africa and Asia. Although the majority of dairy cows are found there, their annual milk production is lower than in temperate systems. These low performance result in a high demand for natural resources, low nitrogen use efficiency, and high environmental emissions per unit of milk produced. Hence, there is a strong need to increase animal performances in tropical dairy systems. The aim was therefore to highlight future challenges and perspectives related to tropical dairy cattle nutrition based on results of different trials conducted by our group in the tropics.

Rumen-degradable protein intake was adjusted to the nitrogen (N) requirements of rumen microbes in a study in Peru with lactating cows grazing a legume-grass sward. Lowest rumen-degradable protein intake reduced urinary N excretion and linearly increased efficiency of N use for milk synthesis from 0.20 to 0.25 g milk N/g N intake. Moreover, a study conducted in El Salvador showed that a tropical legume silage (Jackbean) can replace 55 % of crude protein from soybean in diets of dairy cows without any negative effects on milk yield, while increasing N use efficiency from 0.13 to 0.15 g N/g N intake. In this line, common methods to estimate metabolisable energy concentrations in ruminant feeds do not appear to be valid for tropical diets, and results of a study with heifers show that estimated efficiency of rumen microbial protein (MCP) synthesis is lower (5 g MCP/MJ ME intake) than values published in the literature for temperate cattle diets (10.1 g MCP/MJ ME intake), hampering the adjustment of N intakes to actual requirements of rumen microbes and their host.

Evidence exists of the potential to increase resources use efficiency by tropical cattle, therefore further research is needed to develop and validate scientific methodology for an accurate evaluation of the nutritive value of tropical ruminant feeds. Moreover, differences in rumen protein turnover and protein requirements should be quantified to adjust rumen-degradable protein intake to actual requirements, and to thereby enhance N use efficiency in dairy feeding.

**Keywords:** Nitrogen partitioning, protein use efficiency, tropical dairy cattle

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## ***In vitro* Rumen Fermentation of *Sauropus androgynus* (L.) Merr. Compared to Hays of Different Quality**

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Katuk leaves (*Sauropus androgynus* (L.) Merr) have a high crude protein (CP) content. Supplementing Katuk leaves to lignified forages, e.g., crop residues that are low in metabolisable energy and CP will increase the nutritional value of the feedstuffs.

The main objectives of this study were to evaluate the chemical composition, the estimated metabolisable energy (ME) and net energy for lactation (NEL) values of Katuk leaves and to evaluate the effect of blending Katuk leaves with hay of differing quality on *in vitro* rumen fermentation using an *in vitro* gas production technique, namely the Hohenheim gas test (HGT).

Variation in the chemical composition was observed among feedstuffs at 45.3 g kg<sup>-1</sup> DM (hay low quality) to 333 g kg<sup>-1</sup> DM (Katuk leaves) for CP, 56.3 g kg<sup>-1</sup> DM (low quality hay) to 111 g kg<sup>-1</sup> DM (Katuk leaves) for ash, 3.6 g kg<sup>-1</sup> DM (low quality hay) to 30 g kg<sup>-1</sup> DM (high quality hay) for ether extract. The greatest fibre (aNDFom) value was 700 g kg<sup>-1</sup> DM (low quality hay). Low quality hay had the highest value of lignocelluloses (ADFom, 450 g kg<sup>-1</sup> DM) and Katuk leaves had the lowest ADFom value (192 g kg<sup>-1</sup> DM). Low quality hay had also the highest content of lignin (ADL, 33.9 g kg<sup>-1</sup> DM).

Net gas production value of feedstuffs was found between 15.8 and 54.2 ml/200 mg dry matter (DM). The estimated ME and NEL contents of feedstuffs ranged from 7.57 to 10.34 MJ kg<sup>-1</sup> DM and from 4.32 to 6.27 MJ kg<sup>-1</sup> DM, respectively. Using another equation to estimate ME values, similar results were observed with values ranging from 7.02 to 11.43 MJ kg<sup>-1</sup> DM. Overall, according to chemical composition, *in vitro* gas production and resulting ME and NEL estimation, the mixture of high quality hay with 20 % of Katuk leaves was the best blend in terms of nutritive value for ruminants.

**Keywords:** Chemical composition, gas production, katuk leaves, metabolisable energy

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## Cattle Production under Grazing with Improved Forages in the Lowland Tropics of Colombia

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The increase in global population and changes in people's lifestyles and diets during the last years have generated a high demand for animal protein sources. In Colombia, most of the area dedicated to livestock production is managed under extensive and inefficient production systems. The International Center for Tropical Agriculture (CIAT) is working on the sustainable intensification of livestock systems through improving their efficiency and productivity while mitigating negative environmental effects such as deforestation, and greenhouse gas emissions. A critical pathway to achieve sustainable intensification of livestock systems is through the selection and breeding and subsequent adoption of improved forages, which can either be used as stand-alone technology or be part of a (e.g., silvo-pastoral) system. Silvo-pastoral systems have shown excellent results in terms of higher biomass production, better nutritional quality, positive environmental effects and higher animal stocking rates. At CIAT's headquarters in Colombia, we evaluated the live-weight gains (kg/ha) of twelve steers (age: two years) randomly distributed in three groups, applying one grazing treatment to each group. The three treatments under evaluation were: T1 - *Brachiaria* Hybrid, CIAT BR02/1752 cv. Cayman, T2 - cv. Cayman plus *Canavalia brasiliensis* CIAT 17009, and T3 - cv. Cayman plus *C. brasiliensis* CIAT 17009 plus *Leucaena diversifolia* ILRI 15551. In an experimental block design, each treatment was applied on plots of 3,300 m<sup>2</sup> with three repetitions during a period of seven months.

The highest average live-weight gains were observed for T3 (552 kg ha<sup>-1</sup>), followed by T2 (392 kg ha<sup>-1</sup>) and T1 (227 kg ha<sup>-1</sup>), respectively. This suggests stocking rates (LU = 450 kg) of 2.5 (T1; 1,104 kg ha<sup>-1</sup>), 2.7 (T2; 1,219 kg ha<sup>-1</sup>), and 3.2 (T3, 1,423 kg ha<sup>-1</sup>) animals per hectare, respectively. Multiple comparisons with Duncan and Turkey tests show significant differences among the three treatments, with T3 being the best performing ( $p \leq 0.05$ ), followed by T2 and T1.

The results suggest that multi-strata silvo-pastoral systems, such as the one evaluated in T3, can be an excellent alternative for improving the productive parameters of the cattle sector and in addition to that, can provide valuable environmental benefits.

**Keywords:** Improved forages, live-weight gain, silvo-pastoral systems, stocking rate

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## Increasing Milk Production Using Dormant Alfalfa (*Medicago sativa* L.) in the Peruvian High Plain (Puno)

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Cattle production in Puno is the main economic activity in the region. Puno is the fifth milk producer in Peru and dairy has been developing at a fast rate during the last decade. An interesting alternative implemented within the last years by regional and NGO's initiatives includes the introduction of dormant alfalfa, a cultivar adapted to high altitude (4000 m a.s.l.) and extreme cold weather conditions. Particularly alfalfa W350 with a dormancy type of 3.8 is able to survive under harsh climate conditions, remaining dormant (May - October) to then start growing again during the rainy season from November to April. This study was conducted with a semi-structured survey comprising 24 dairy producers from 7 districts in the provinces of Puno, Huancane, Lampa and Melgar. The aim of the study was to identify the milk cost of production and the main components of dairy farms in a system using alfalfa as the main forage. SPSS software was used and generated three groups by size. Milk production cost were 0.27, 0.24 and 0.23 € l<sup>-1</sup> for the small, medium and large producer, respectively. The average milk production per cow was 8.0, 9.9 and 10.2 l d<sup>-1</sup> for the small, medium and large scale farms. There is a difference between the proportion of lactating cows for differently sized farms with 39, 33 and 47 % for small, medium and large dairy producers. The main cost components in milk production are labour and feeding with 44 and 39 %, respectively. The cost of milk production in Puno where dormant alfalfa is used as pasture forage was less in comparison with the intensive system developed on the Peruvian coast around Lima or Arequipa. Results show that the use of dormant alfalfa can help dairy producers in the High Plain to provide food security and increase family income.

**Keywords:** Dairy farmers, dormant alfalfa, milk production cost

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## Diet Selection and Ingestive Behaviour of Lambs Fed Diets with Increasing Levels of Whey Permeate

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The selection of feed by ruminants may have an impact in their productivity due to the nutritional value of the different diets, changing the time spent in feeding and rumination, and the size of ingested particles. The aim of this study was to evaluate the diet selection and ingestive behaviour of lambs fed diets with levels of dry whey permeate (WP) during different times along the feedlot period. Twenty four crossbred  $\frac{1}{2}$  Dorper  $\times$   $\frac{1}{2}$  Santa Inês non-castrated male lambs with four months of age and  $24 \pm 3.2$  kg body weight were used. A completely randomised design with six replicates was used. The WP replaced ground corn in the diet (0.0, 5.0, 12.5 and 25.0 % of dry matter (DM)). Lambs were fed *ad libitum* for 90 days with diets composed of *Cynodon dactylon* hay (64 % DM) and concentrate feed (36 % DM). We measured the time of feeding, rumination and idling, and the average particle size (APS) of leftovers, at 9, 37, 71 and 86 days of feedlot. Data were analysed in a mixed model with fixed effects being WP, feedlot time and their interactions (5 % significance). There was no interaction between WP and feedlot time. Comparing days 9 and 86, there was an increase in large particles (37.11 vs. 55.87 %) and decrease of small particles (16.32 vs. 4.90 %) in the leftovers. It's likely that selection is related to higher energetic demand of finishing lambs compared with the ongoing rumen development of young lambs. Intake of large particles is usually a natural way to stimulate the rumen motility. Feeding was higher at day 9 (342 min) than at day 37 (289 min), reflecting the time demand for large particles. This is also supported by the higher rumination at day 9 (587 min) than at day 37 and day 86 (533 min on average), which is in line with the lower APS at day 9 (8.98 mm) compared to day 86 d (14.67 mm). The behaviour and the diet selection demonstrate how lambs change their feeding patterns, and that the substitution of corn by WP does not affect this process in feedlot conditions.

**Keywords:** Feeding, leftover, particle size, rumination

## Feeding of Dairy Cows, Beef Cattle and Pigs in Peri-/Urban Agriculture in Ouagadougou, Burkina Faso

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Urban and peri-urban livestock keeping serves socio-economic functions and has positive effects on food security. But livestock keepers in cities often face lack of feed, and feeding therefore accounts for the most important variable costs of their activity. As quantitative data on peri-/urban feeding strategies remain scarce, the present study tried to help filling this gap. Within the BMBF-funded UrbanFood<sup>Plus</sup> project (GlobE 03/A242-A), feeding strategies were monitored in 10 visits between 11/2014 and 03/2016. Twenty-one farms representing the diversity of production systems in Burkina Faso's capital Ouagadougou were selected. Data was collected, *inter alia*, on individual feed intake and live weight (LW) development of 1091 animals.

Apart from three completely pasture-based ruminant farms, all other farms practiced homestead feeding. Additionally, animals were only sent for grazing by one, one and three farmers during early dry, late dry and rainy season, respectively.

In terms of quantity of feed offered (on dry matter basis - DM), beef cattle predominantly received roughages and crop by-products (90%), in particular cereal straws (18%), grass hay (19%), residues from corn milling (31%) and brewers' grains (13%). Dairy cattle were also fed roughages (58%), particularly grass hay (23%), and a substantially higher share of protein plus energy feeds (41%). These comprised commercial dairy concentrate (24%), corn milling residues (12%) and brewers' grains (11%). Pigs were mainly fed with brewers' grains (44%), corn milling residues (28%) and commercial concentrates (14%), corresponding to a 62% and 34% share of the concentrates and roughages.

Feed intake ( $\text{g DM kg}^{-0.75} \text{ LW}$ ) during homestead feeding of beef cattle averaged  $97 \pm 24$  as compared to  $73 \pm 50$  for dairy cattle. Pigs were in most cases exclusively stall fed and consumed  $99 \pm 63$  of feed.

The data shows that long-term on-farm monitoring allows for credible insights into farmers' feeding practices; it points to a high variability in their strategies, which are partly determined by seasonal fodder availability and prices. Further analyses will allow comparing nutrient and energy intake of the animals to their performances and thus conclude on resources use efficiency.

**Keywords:** Animal nutrition, beef, Burkina Faso, cattle, dry matter intake, pig, urban and peri-urban agriculture

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## Effect of Sweet Potato Vine Silage and Urea Molasses Supplementation on Feed Intake, Diet Digestibility and Methane Emissions of Heifers on a Poor Quality Tropical Diet

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Given their high nitrogen concentration and low costs under smallholder conditions, sweet potato vine silage (SPVS) and urea-molasses blocks (UMB) are recommended as alternative supplementation for ruminants in tropical regions.

This study used a  $3 \times 2$  Youden square design to investigate SPVS and UMB supplementation using 6 crossbred Holstein-Friesian  $\times$  Boran heifers of  $153 \pm 16.9$  kg body weight (BW). Animals were stratified by BW and allocated to 3 diets, with the basal diet (BD) being offered *ad libitum* (at 2 % of BW) and consisting of 61.4 % wheat straw and 38.6 % Rhodes grass hay (on dry matter basis - DM). Diet SPVS contained 80.4 % of BD plus 19.6 % of SPVS and diet UMB was identical to diet BD but animals had *ad libitum* access to licking blocks containing molasses (35 %),  $\text{CaHPO}_4$  (19 %), urea (10 %), NaCl (10 %) and cottonseed meal (5 %). Quantitative and qualitative data on feed intake and fecal excretion was collected during two 7-day experimental periods; methane emission was determined during 3 days of respiration chamber measurements. Both experimental periods were preceded by 21 days of adaptation to the diets. Samples of feed offered, refused and of feces were analysed for proximate composition following standard protocols. Data was tested for normality and subjected to the mixed model procedure of SAS with diet as fixed and animal as a random factor.

Heifers on SPVS had a higher ( $p < 0.05$ ) intake ( $\text{g kg}^{-0.75} \text{ BW d}^{-1}$ ) of crude protein ( $6.9 \pm 1.71$ ) than those offered UMB ( $5.0 \pm 0.36$ ) and BD ( $5.6 \pm 0.39$ ), whereas there was no treatment difference ( $p > 0.05$ ) in organic matter (OM) intake ( $63 \pm 9.7$ ) and OM digestibility ( $518 \pm 20.4 \text{ g kg}^{-1}$ ). Daily  $\text{CH}_4$  emissions were not different ( $p > 0.05$ ) between diets when expressed per animal or per kg OM intake. However, when expressed per unit of digested feed (liters  $\text{kg}^{-1}$  DOM),  $\text{CH}_4$  emissions were lower ( $p < 0.05$ ) in group SPVS ( $112 \pm 17.5$ ) as compared to UMB ( $130 \pm 4.1$ ) and BD ( $129 \pm 14.1$ ).

We conclude that a supplementation with about 20 % SPVS in the diet DM slightly improves nitrogen intake and decreases enteric methane emission in cattle on poor quality roughage feeds.

**Keywords:** Cattle, greenhouse gas emission, low-quality roughage, supplementation

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## Effect of Sweet Potato Vine Silage and Urea-Molasses Blocks on Nutrient Intake, Nitrogen Balance and Rumen Microbial Protein Synthesis of Crossbred Heifers on a Poor Quality Diet

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Supplementation of low-quality roughages with sweet potato vine silage (SPVS) or urea-molasses blocks (UMB) is considered to improve livestock production by enhancing microbial fermentation in the rumen and thereby nutrient and energy supply to the host.

A 3×2 Youden square design was used to test the effects of SPVS or UMB supplementation on nutrient intake, nitrogen (N) balance, and ruminal synthesized microbial N during two experimental periods with each 21 d of adaptation and 7 d of total urine and feces collection. Six Holstein Friesian-Boran crossbred heifers with a body weight (BW) of 153 kg (standard deviation [SD] 16.9) were allotted to three groups of two animals each. Animals were fed individually with a basal diet alone or supplemented with SPVS (basal diet + SPVS [2.5% BW, as-fed basis]) or UMB (basal diet + UMB [*ad libitum*]). The basal diet consisted of 61.4% wheat straw and 38.6% Boma Rhodes hay (on dry matter [DM] basis) and was offered at 2% of BW (as-fed basis).

Daily DM intake and digestibility of DM did not differ between diets ( $P > 0.05$ ). Mean daily DM intake and digestibility of DM were 3.1 kg d<sup>-1</sup> (SD 0.6) and 50.3 g/100 g DM (SD 3.1), respectively. Similarly, there were no differences ( $P > 0.05$ ) in daily N intake (41.4 g d<sup>-1</sup> [SD 8.9]) or daily urine N (19.8 g d<sup>-1</sup> [SD 4.4]) and fecal N (26.7 g d<sup>-1</sup> [SD 5.1]) excretions of heifers fed the three diets. Nitrogen balances were negative for all diets, but less in heifers consuming SPVS (-2.7 g d<sup>-1</sup>) compared with those receiving the basal diet alone (-6.2 g d<sup>-1</sup>;  $P = 0.02$ ) or supplemented with UMB (-7.2 g d<sup>-1</sup>;  $P = 0.01$ ). Urinary purine derivatives excretion and estimated ruminal synthesized microbial N were not affected by diet ( $P > 0.05$ ). Urinary purine derivatives excretion and estimated duodenal microbial N flow were 42.6 mmol d<sup>-1</sup> (SD 11.7) and 22.2 g d<sup>-1</sup> (SD 9.4), respectively.

The increased N balance in heifers consuming SPVS clearly indicates that supplementation of a low-quality roughage diet with SPVS can improve nutrient utilisation and thus ruminant production in the Tropics.

**Keywords:** Nitrogen, supplementation, sweet potato vines, tropical cattle, urea blocks

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## Effect of Exogenous Administration of Oxytocin on Follicular Dynamics and Milk Contents in Partially Lactating Nilli-Ravi Buffaloes

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In Pakistan, oxytocin is being used extensively in buffalo for milk let-down especially near terminal lactation when it refuse to accept calf for milk let-down. Therefore, exogenous oxytocin is an alternative of calf suckling and the main solution of buffalo milk letdown for dairy farmers but at same time it may be cause of erratic estrous cycle and infertility. Hence, a study was designed to know the effect of different concentration of oxytocin on follicular dynamics and milk contents in Nili-Ravi buffalo. Eight experimental buffaloes were synchronised with single injection of PGF2 after ultrasonography. Daily single injection of oxytocin to each animal was 15, 30 and 45 IU, respectively while the control was injected with normal saline for 100 days. Ultrasonography was done thrice a week to monitor follicular dynamics during whole estrous cycle. Milk (n=400) was collected and analysed for its contents analysis with milkoscan. Results revealed that size of dominant follicle on left ovary was remarkably different in 30 IU and 45 IU of oxytocin treatments compared to 15 IU and the control, and the number of large follicles was significantly ( $p < 0.05$ ) different from control and 15 IU. Large follicles were lowest in number at 45 IU. On the right ovary, total follicles and small follicles counts were considerably ( $p < 0.05$ ) higher in 45 IU than 0 IU, 15 IU and 30 IU while sizes of dominant follicles were different significantly ( $p < 0.05$ ) in 0 IU, 30 IU and 45 IU. Medium and large follicles disclosed same trend in all treatments. Among the milk contents, percent fat increased significantly ( $p < 0.05$ ) at the peak dose (45 IU) while solid non-fats, density, lactose, protein, solids, freeze point and pH decreased with respect to the control. It was concluded that oxytocin had limited effect on follicular dynamics with lowest counts of medium follicles in all treatments. Further, it was confirmed that milk fat increased with the increase in oxytocin application.

**Keywords:** Buffalo, exogenous, follicles, milk, oxytocin

## Performance of Weaned Rabbit Bucks Fed Graded Levels of African Yambean in Cassava Peel Meal-Based Diets

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A total of 40 crossbred weaned rabbit bucks with an average initial body weight of  $634 \pm 1.50$ g were used to study the effects of dietary inclusion of graded levels of African yambean (AYB) in cassava peel meal (CPM) based diets on performance. Phytochemical screening of the AYB (raw and processed) and CPM was carried out. Four experimental diets were used in this study containing graded levels of AYB at 0, 10, 20 and 30 percent respectively with CPM fixed across the treatments at 25 percent. The rabbits were divided into 4 treatments; 10 rabbits per treatment, each serving as a replicate and were randomly assigned to the experimental diets in a completely randomised design (CRD). The rabbits were managed based on standard experimental procedures. Feed and water were given *ad libitum*. Blood samples for serum biochemical and haematological indices were collected before and after the feeding trial. Data on growth performance and linear body measurement were recorded. The calcium and globulin were significantly different across treatments ( $p < 0.05$ ) for the initial and final blood analysis. Serum cholesterol was reducing as the level of AYB was increasing. Results of growth performance were significantly different ( $p < 0.05$ ) for final weight, total weight gain and feed conversion ratio (FCR) while total feed intake was not significantly different ( $p > 0.05$ ). Dressed weight showed significant difference ( $p < 0.05$ ) between treatments. Mean score for sensory evaluation of palatability and acceptability of rabbit meat showed significant difference ( $p < 0.05$ ) between the two processing methods (scalding and singeing). Colour, flavor, taste and overall acceptability of scalded carcass did not have any significant effect ( $p > 0.05$ ) while singed carcass significantly differed in texture, flavor, appearance and overall acceptability compared to scalded carcass. The economics of production showed that though diet with 30 percent AYB had the least cost/kg diets with higher FCR. Feed with 20 percent AYB inclusion level did not record adverse effect on the performance characteristics. From this study, AYB can be included up to 20 percent level with cassava peel meal for weaned rabbit bucks without adverse effects on their performance, blood characteristics and cost of production.

**Keywords:** African yam bean, performance, rabbits

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## The Constraints and Opportunities in the Compounded Feed Production and Supply Chain in Uganda

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Feed supplements enhance productivity by supplying deficient micronutrients forages. There are problems with compounded feeds in Uganda. This study studied the factors that affect production, supply and quality of compounded feeds. A total of 87 actors in the compounded feeds value chain were interviewed. They included raw material suppliers, agro-industrial processors, feed producers, feed traders, service providers and consumers. Results showed that the concentrate feeds supply chain is complex, involving several actors. The large scale feed producers supply chains are longer and complex. They are mainly based in Kampala and other bigger towns and have supply networks to rural and peri-urban areas. They produce 20 % of the feeds used on farms. The feed supply chains involving small scale producers are shorter and simpler. The small scale producers are present in urban, peri-urban and rural areas. They 'tailor make' feeds for small scale farmers according to their needs. They produce 80 % of compounded feeds used on farms. Actors identified weak enforcement of national feeds regulation policy as the main reason for poor quality supplement feeds on the market. Farmers attributed this to the current low milk yields on farms. Most farmers have resorted to formulating homemade feeds despite glaring lack of technical knowledge and skills. As a result, only 13 % of interviewed farmers reported using compounded feeds. Use of supplementary feeds is positively though not significantly correlated with milk production. The commonly used feed supplements were maize bran (75.8 %), dairy meal (15.2 %) and homemade rations (6.1 %). Some 4.1 % of farmers use brewers waste. Farmers do not use calf pellets. The average price per kg of commonly used feed supplements were USD 0.14 for maize bran, USD 0.33 for dairy meal and USD 0.15 for homemade rations. Feed testing facilities are costly and inaccessible to value chain actors in Uganda. There is no feed manufacturers association to champion issues in the feed industry. These factors have greatly affected production and supply of quality livestock feeds required to boost animal productivity. There is urgent need to establish a feed manufacture education, training and self-regulation and accreditation system in the industry.

**Keywords:** Concentrates, feed policy, feed regulation, feeds, value chain

## Effect of Tannin and Soybean Oil Supplementation on Gas Production, Degradability and Ruminal Fermentation

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Tannins and soybean oil are available as feed supplement to ruminants in the semi-arid region of Brazil and potentially change the degradability of nutrients and gas production. The aim of this study was to evaluate the influence of diets with condensed tannin (CT) and soybean oil (SBO) supplementation on *in vitro* gas production, degradability and ruminal fermentation characteristics. The inclusion of CT and SBO replaced equal amount of concentrate in dry matter basis. Treatments were T1 = 60 % elephant grass + 40 % concentrate (control); T2 = 60 % elephant grass + 37 % concentrate + 3 % CT (Weibull); T3 = 60 % elephant grass + 35 % concentrate + 5 % SBO; T4 = 60 % elephant grass + 32 % concentrate + 3 % CT (Weibull) + 5 % SBO. The gas production was decreased with inclusion of CT (104 ml g<sup>-1</sup>) and SBO (111 ml g<sup>-1</sup>), with significant interaction between the two supplements (99 ml g<sup>-1</sup>) compared to control (128 ml g<sup>-1</sup>). The effective DM degradability was also reduced to inclusion of CT (31.0 %) and CT-SBO (33.8 %) compared to control (38.4 %). The potential degradability of CP was lower due to SBO (73.5 %) and CT-SBO (80.3 %) inclusion, but higher in NDF potential degradability (71.4 %) than control treatment (84.9 % to CP and 63.8 % to NDF). In terms of effective degradability, CT was the supplement which presented most regular pattern to decrease the degradability of DM, CP and NDF. The effective interaction of supplements is dependent on the type of the nutritional parameter under evaluation. The SBO was the supplement with wider effect on ruminal fermentation, increasing the pH (6.58 vs 6.50) and NH<sub>3</sub>-N (19.5 vs 13.9 ml l<sup>-1</sup> of rumen liquid) in comparison to control. The supplements can be regarded as effectives to control the degradability of nutrients and gas production.

**Keywords:** Lipid, ruminant, secondary metabolite, supplement

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## Improved Region-Specific Emission Factors for Enteric Methane Emissions from Cattle in Nandi County, Kenya

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National greenhouse gas (GHG) inventories in most developing countries, and in sub-Saharan Africa (SSA) in particular, use default GHG emission factors (EF) provided by the Intergovernmental Panel on Climate Change (IPCC) to estimate methane (CH<sub>4</sub>) emissions from livestock – a so-called Tier 1 approach. Due to the fact that these EFs are based on data primarily collected in developed countries in the Northern Hemisphere, there is a high degree of uncertainty associated with CH<sub>4</sub> emission estimates from African livestock systems. Accurate Tier 2 GHG emission reporting from developing countries becomes particularly necessary following the Paris Climate agreement after COP21. Following this need, the objective of this study was to derive region-specific enteric EFs using Tier 2 methodology for cattle under smallholder livestock production systems in Kenya. Data on cattle characteristics and performance was collected from 127 households in 36 villages within three agro-ecological zones (AEZ) in Nandi County, over the duration of one full year. Live weight (LW), growth, milk yield, milk quality and calving were recorded for 1,146 cattle that were grouped by sex and maturity. Analysis of representative feed samples was performed to estimate dry matter digestibility (DMD) of the available feed for each of the AEZs and seasons. DMD ranged from 52–66.6% ( $\bar{x}$ =62.0%). Dry matter intake (DMI) was derived from estimated total energy requirement. DMI and DMD were used to calculate daily methane production using a newly available CH<sub>4</sub> conversion factor to create new region specific EFs.

Enteric CH<sub>4</sub> EFs were: 39.9, 48.5, 30.6, 36.1 and 31.6 kg CH<sub>4</sub>/head/year for mature females, mature males, heifers, steers and calves respectively, the herd weighted mean being 36.5 kg which is substantially lower than the IPCC's Tier 1 estimates for unspecified African adult cattle.

**Keywords:** Africa, cattle, emission factor, enteric methane

## Digestibility, Energy Use Efficiency and Methane Production in Steers Fed at Restricted Levels of Intake

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It is well recognised in ruminants that as intake decreases, nutrients absorption efficiency increases. However, studies conducted on animals fed at below Maintenance Energy Requirements (MER) are inconclusive, with some showing an increase, some no change and some even a decrease in apparent total tract digestibility.

To investigate the effects of feeding level on energy utilisation efficiency and enteric methane production, a feeding trial was conducted using Boran steers (n=12, LW=183.3±4.3 kg [SE], age=18 mo). In a randomised block design, steers were fed at 120%, 100%, 80% or 60% of calculated MER a diet composed mainly of chaffed Rhodes grass hay (dry matter [DM]: 906.5 g kg<sup>-1</sup>; organic matter [OM]: 915.2 g kg<sup>-1</sup>; crude protein [CP]: 57.7 g kg<sup>-1</sup> neutral detergent fibre [NDF]: 729.3 g kg<sup>-1</sup>; metabolisable energy [ME]: 8.3 MJ kg<sup>-1</sup>) for 35d including a 14d adaption period. One sixth of the total energy for the 120% treatment group was fed in a 48:52 cottonseed meal : molasses mixture. Intakes, refusals, faecal and urine output, and enteric methane production were measured. Statistical significance was set at  $p < 0.1$ .

Gross energy intake (GEI; MJ/d) differed between treatments ( $p < 0.02$ ), but digestible energy intake (DEI; MJ/d) did not differ ( $p = 0.24$ ) in the 120% and 100% MER treatments, but were greater than the intakes for the 80% and 60% MER groups ( $p < 0.03$ ). Level of intake did not affect OM or CP digestibility ( $p > 0.54$  and  $p > 0.38$ , respectively). Energy losses through faeces were 44% of GEI, methane; 8.1 and urinary losses; 2.1% but these did not differ from one treatment to another. Methane yield (MY) were 24.1, 23.7, 27.0 and 29.64 (± 1.1 PSEM) CH<sub>4</sub> g per kg DMI for the 120%, 100%, 80% and 60% groups, respectively, with the 60% treatment group being significantly different from the 100% treatment group ( $P=0.09$ ).

The lower DEI and higher energy losses in form of methane emissions at intakes below MER in the present study indicate that energy utilisation in cattle fed below maintenance is not improved and that MY actually increases in cattle fed at low levels.

**Keywords:** Methane yield, sub-maintenance feeding cattle



## The Immuno-Nutritional Effects of Dietary *Astragalus* Polysaccharides on Weaned Pigs under Smallholder Conditions

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The search for alternatives to prophylactic synthetic antibiotic use in weaned pigs due to stress related challenges continues to attract the attention of researchers worldwide. Experiments on-field and in-lab were conducted to determine the effect of crude polysaccharides extracted from dietary *Astragalus membranaceus* (APS) on weanling pigs. We also determined the changes in the growth performance, nutrient digestibility, intestinal morphology and immune response. A total of 40 crossbred weanling pigs aged 28-35 d at an average initial live weight of 8.68 kg were used in the investigation. The experiment was arranged in a completely randomised design with 5 treatments: namely control; AGP chlortetracycline 150 mg kg<sup>-1</sup>, APS 200 mg kg<sup>-1</sup>, APS 400 mg kg<sup>-1</sup> and APS 800 mg kg<sup>-1</sup>. Treatments were replicated four times with 2 pigs per pen over a 28 d experimental period. An experimental diet of corn and soya was formulated according to USA National Research Council nutrient requirements. There were no significant differences in average daily feed intake, average daily gain and gain to feed ratio although modest numerical gains were recorded. APS significantly improved the percentage apparent nutrient digestibility. Hematological analysis on day 14 and at the end of the experiment revealed significant increases in leukocytes, lymphocytes, and blood platelet count but not on number of erythrocytes. Evaluation of serum concentrations of immunoglobulin cytokines interleukin 4, interleukin 6, interleukin 10 and interferon-gamma revealed no significant differences in the serum concentrations. Dietary supplementation of crude polysaccharides isolated from *Astragalus membranaceus* could be an alternative to replace antibiotic growth promoters under smallholder conditions.

**Keywords:** *Astragalus* polysaccharides, growth performance, immune response, pigs

## Chemical and Nutritional Characteristics of Traditional Meat Products of Borana Community in Marsabit County, Kenya

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The Borana community, who are pastoralists in northern Kenya, has well established traditional meat processing and preservation practices. The preserved meat products help to contribute to household food security, particularly during periods of droughts. The meat products are produced mainly from cattle (*Bos indicus*) goat (*Capra hircus*) and camel (*Camelus dromedarius*) meat. The processing of these products involves the use of preservation techniques such as striping, drying and heating, with or without the use of various added ingredients. However, upscaling of the traditional meat conservation has been constrained by lack of adequate information on the nutritional content and quality of the products. The objective of this study was therefore, to determine the nutritional composition and indicators of spoilage in traditional meat products of the Borana Community in Marsabit County, Kenya.

Traditionally processed meat samples were collected in Marsabit County. The proximate composition, quality indices and mineral content of the samples were analysed using the methods of the Association of Official Analytical Chemists (AOAC).

The result showed that traditional meat products were high in protein, with mean contents ranging from 55.8–72.5%. The minerals calcium, magnesium, iron and potassium ranged from 35.8–110 mg/100 g, 52.8–60.7 mg/100 g, 4.5–7.4 mg/100 g, and 701–826 mg/100 g, respectively. The fatty acid composition showed that traditional beef and goat meat products contained good amount of monounsaturated oleic acid at mean levels of 37.2% and 39.2% respectively. The linoleic acid content for the same products was 13.3% and 13.5%, respectively. Peroxide Value (PV), ranged from 1.8–2.6 mg Eq. kg<sup>-1</sup>, acid value was 0.01% while Thiobarbituric Acid (TBA) ranged from 0.32–0.52 mg malondialdehyde (MDA) kg<sup>-1</sup>. The PV, acid value and TBA levels were below the value associated with meat spoilage during the expected shelf life. Hence there is good potential for upscaling of the production of these traditional meat products including exploring options for packaging and selling products to increase income while contributing towards improved food security among the community.

**Keywords:** Borana, drying, Marsabit, meat, nutrition composition, quality, traditional

## Detheobromination and Improvement of Nutritional Quality of Cocoa Pod Husk through Solid State Fermentation Using *Rhizopus stolonifer*

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Cocoa pod husk (CPH), a major agro-industrial waste in Nigeria, has a potential value as a low-cost unconventional feedstuff for livestock. Its effective use is limited by its poor nutrient composition, mainly due to its high fibre, low protein level and high theobromine content. Chemical methods for eliminating theobromine have been carried out successfully but these procedures are expensive and cannot be adopted by subsistence farmers in the cocoa industry due to the use of chemically-treated adsorbents and sophisticated equipment.

The development of simple, effective and affordable procedures for the detheobromination of cocoa pod husk is thus critical to maximise usage of the husk by farmers. Therefore, cocoa pod husk meal was taken through a solid state fermentation process involving *Rhizopus stolonifer* as its starter culture for a period of two weeks and analysed for theobromine concentration, fibre fractions and proximate composition. This study evaluated the effect fermentation period has on proximate composition and theobromine concentration of cocoa pod husk meal (CPHM).

The results showed that the proximate composition of CPHM improved during fermentation. Crude protein significantly had a total increment of 95 % while crude fibre and crude lipid showed significant decrease with total reductions of 14 % and 22 % respectively after 2 weeks of fermentation. Theobromine content in the CPHM decreased significantly ( $p < 0.05$ ) with a total reduction of 75 %. Fibre fractions were also enhanced with neutral detergent fibre (NDF) decreasing from 92 % (control) to 66 %. The increase in crude protein, reduction in crude fibre and theobromine contents is indicative of improvement in the nutritional status of CPHM. In this study, although the fermentation period was 2 weeks some components such as CP did increase significantly after day 3, but later decreased to reach its peak again on day 14 while the theobromine content showed a gradual reduction until day 14. Therefore, a minimum of 2 weeks of *Rhizopus stolonifer* fermentation could be considered as an optimum fermentation period to significantly improve the proximate composition and reduce the theobromine level of CPH.

**Keywords:** Cocoa pod husk, detheobromination, proximate composition, *Rhizopus stolonifer*, solid state fermentation

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## Fermentation Quality and Chemical Composition of Napier Pakchong 1 Silage Supplemented with Lactic Acid Bacteria

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The objective of this study was to evaluate effect of lactic acid bacteria supplementation on fermentation quality and chemical composition of Napier Pakchong 1 silage. Lactic acid bacteria (LAB) were extracted from corn silage. The isolates was grow in MRS agar plate at 37 °C for 48 hours in anaerobic condition. The effect of LAB supplementation on fermentation quality and chemical composition of Napier Pakchong 1 silage were evaluated using in a completely randomised design. Napier Pakchong 1 Silage was divided into two groups (control and supplemented with LAB with  $1 \times 10^5$  cfu ml<sup>-1</sup>). One kilogram of Napier Pakchong 1 grass was supplemented with 10 ml of LAB. Silage was collected at day 14, 21, 28 and 35 of fermentation. Samples were analysed for pH, lactic acid concentration, chemical composition by proximate analysis and detergent method. It was found that pH of Napier Pakchong 1 silage supplemented with LAB was lower than of the control. Lactic acid concentration was higher in Napier Pakchong 1 silage supplemented with LAB. The crude protein (CP) and acid detergent fibre (ADF) concentrations of Napier Pakchong 1 silage declined with increasing ensiling time. The CP and ether extract (EE) concentration of Napier Pakchong 1 silage supplemented with LAB was higher than the control (8.6 vs 8.0% and 2.5 vs 2.3%) The crude fibre (CF) concentration of Napier Pakchong 1 silage supplemented with LAB was higher than in the control. It can be concluded that LAB supplementation increased the fermentation of Napier Pakchong 1 silage and decreased the nutrient deterioration of Napier Pakchong 1 silage.

**Keywords:** Chemical composition, fermentation quality, lactic acid bacteria, napier Pakchong 1, silage



# Agricultural and food technology

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## Oral Presentations

- SELORM Y. DORVLO, AHMAD ADDO, FRANCIS KEMAUSUOR,  
STEPHEN ABENNEY-MICKSON, ULRIK HENRIKSEN, JESPER  
AHRENFELDT, MATHIAS NEUMANN ANDERSEN:  
**Clean Cook Stove Technology for Artisanal Palm Oil Clarifi-  
cation and Biochar Production in Ghana** 384
- CORNEL ADLER, AGNÈS FLORE MOUALEU:  
**Vacuum Storage to Protect Durable Stored Products at  
Different Moisture Contents** 385
- EMMANUEL WOKULIRA MIYINGO, OLIVER HENSEL,  
BARBARA STURM:  
**Pineapple Processing in Central Uganda** 386
- FARAH MRABET, VICTOR TORRES TOLEDO, ANA SALVATIERRA,  
JOACHIM MÜLLER:  
**On-Field Assessment of an Innovative Solar Powered Milk  
Cooling System in Tunisia** 387
- AFIFAH AFIFAH RAHMI, YEFISI YEFISI MALRIANTI, GUSVITA  
GUSVITA WIDIA:  
**Utilisation of Different Types of Natural Dye Source as a Smart  
Packaging Indicator to Detect Fillet Damage of Chicken Meat  
During Storage** 388

## Posters

- THOMAS DAUM, REGINA BIRNER:  
**The Neglected Governance Challenges of Agricultural  
Mechanisation in Africa – Insights from Ghana** 389
- PEDRO JULIAN GARCIA GUARIN:  
**Thermal Modelling of a Solar Tunnel Dryer for Drying  
Parsley (*Petroselinum sativum*)** 390
- EUNICE MEWA, MICHAEL OKOTH, CATHERINE KUNYANGA:  
**Effect of Drying Air Temperature and Slice Thickness on the  
Colour, Texture and Rehydration Parameters of Dried Beef** 391

- ELISHA O. GOGO, ARNOLD M. OPIYO, CHRISTIAN ULRICH,  
SUSANNE HUYSKENS-KEIL:  
**Ziplock Packaging Film for Reducing Quantitative and  
Qualitative Losses of Vegetable Amaranth Leaves (*Amaran-  
thus cruentus* L.)** 392
- CAETANO LUIZ BEBER, IOANNIS SKEVAS, SEBASTIAN  
LAKNER, LUDWIG THEUVSEN:  
**Determinants of Technical Efficiency of Dairy Processing  
Firms in Southern Brazil** 393
- FRANCESCO GARBATI PEGNA, PIETRO BARTOLINI, LHOUS-  
SAINÉ EL RHAFFARI, SOUMIA FAHIM, CLAUDIA ZUCCA,  
ENRICO BONAIUTI, QUANG BAO LE:  
**Improving the Date Production Chain in the Moroccan Oases  
through Small Mechanisation Inputs to Support the Govern-  
mental Development Strategies** 394
- FERNANDO LOZANO OSORNO:  
**Determination of the Design and Selection Characteristics of  
Potato Diggers for Animal Draught in Colombia** 395
- STANISLAV FLEKAC, JAN BANOUT:  
**Use of Computational Fluid Dynamics Modelling Tool for  
Assessment of Airflow Distribution in a Double-Pass Solar  
Drier** 396
- THIBAUT DE MOOR, MIRJA MICHALSHECK:  
**Hoe, Bullocks or Tractor for Ploughing, Why Do Farmers  
Choose What?** 397
- YUSTO YUSTAS, VALERIAN SILAYO, FRIEDER GRAEF,  
LUTENGANO MWINUKA:  
**Participative Development of a Top-Lit-Up-Draft Reactor for  
Simultaneous Cooking and Biochar Making** 398
- DINAH KIRIGIA, HEIKO MIBUS-SCHOPPE, TRAUD WINKEL-  
MANN, REMMY KASILI:  
**Effects of Age, Storage Temperature and Duration on Total  
Phenolics, Flavonoids and Antioxidants in African  
Nightshade** 399
- JACKLINE AKINYI OGOLLA, CHRISTIAN DEDE, STEVE  
MEYERS, BASTIAN SCHMITT, MICHAEL OKOTH, OLIVER  
HENSEL, BARBARA STURM:  
**An Optimised Solar Camel Milk Powder Processing Plant for  
Rural Arid and Semi-Arid Regions** 400
- ZIBA BARATI, SAJID LATIF, JOACHIM MÜLLER:  
**Optimisation of Enzymatic Treatment for Cassava Root  
Peeling** 401

GUNDULA FISCHER, SIMON WITTICH, BEN LUKUYU, GABRIEL MALIMA, JACQUELINE RUGALABAM, DAVID NGUNGA, LEONARD MARWA, GREGORY SIKUMBA: <b>Gender Implications of the Introduction of Forage Chopper Machines</b>	402
ROSALIZAN MD SALEH, BARBARA STURM, OLIVER HENSEL: <b>Drying Kinetics of Purple Flesh Sweet Potato Grown in Malaysia</b>	403
MAKGAFELE LUCIA NTSOANE, DHARINI SIVAKUMAR, MANUELA ZUDE-SASSE, PRAMOD MAHAJAN: <b>Integrated Postharvest Technologies for Improved Post- harvest Handling of Mango</b>	404
GÖTZ UCKERT, JOHANNES HAFNER, ANTHONY KIMARO, FRIEDER GRAEF, OGOSSY GASAYA SERERYA, MICHELLE BONATTI, STEFAN SIEBER: <b>Enhanced Food Security via Adoption of Improved Cooking Stoves and Local Wood Plantations in Tanzania</b>	405
RICARDO ROMERO PEREZ GROVAS, BERT KOHLMANN, SAM BENTSON, MARIA FERNANDA ROMERO RUBIANO, VICTOR ARBOLEDA: <b>Effect of Improved Stoves on Wood Consumption and Particulate Matter and Carbon Monoxide Production</b>	406

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## Clean Cook Stove Technology for Artisanal Palm Oil Clarification and Biochar Production in Ghana

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The method of heat provision for artisanal palm oil production is riddled with inefficient systems which create unfavourable working conditions (use of spent tyres, smoke filled work tents etc.) for the women who engage in this process. This creates health hazards for the women and sometimes the children they carry along to work. This study therefore sought to produce a cook stove that provide a healthy work environment, is efficient, easy to use, and affordable for medium scale clarification of palm oil. Further it should have a sustainable source of fuel (biomass from processing the palm fruits) and simultaneously produce heat and biochar. Since the adopted design procedure was iterative, eight preliminary tests were conducted; each an improvement of the previous stove tested. After obtaining the best stove configuration, design calculations were done and the final stove fabricated and tested. The final stove consisted of a cut out barrel, a chimney, a grate, insulation for the stove and other additions to make handling easier. At the end of the stove evaluation tests, which were done by the water boiling tests and controlled cooking tests, the thermal efficiency of the stove was found to be  $32.59 \pm 7.11$  % representing a 400 % increase in efficiency when compared with the local replica stove. The cook stove can process approximately 103 litres of press liquor into 23 litres of palm oil within 55 minutes for one cycle of clarification while running on 10 kg of fuel mix and has biochar yield of 5 %. Also the stove provides a healthy work environment with a maximum CO emission of 5 ppm. Overall, the study showed that palm oil clarification with the designed cook stove can be done in an affordable, self-sustaining and smokeless work environment while recovering some biochar at the end of the process.

**Keywords:** Biochar, biomass, CO emission, cook stove, palm fruit fibre, palm kernel shell

## Vacuum Storage to Protect Durable Stored Products at Different Moisture Contents

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Durables in the tropics are easily attacked by pest insects competing with man for resources. These insects increase product moisture contents by respiration and thus enable the development of mycotoxin-producing fungi. In warm climates stored product insects may already attack in the field. Consequently, the harvest may already be contaminated with life insects. A proper storage should thus not only avoid immigration of insects along volatile cues but should also control insects already developing in grains, pulses, dried tubers, oil seeds or nuts. This aim can be achieved in a sustainable way by vacuum storage. Because a vacuum proves a gas-tight and insect-proof seal and at the same time limits oxygen available to insects in the product. Studies with wheat grains in vacuum bags showed rapid mortality of all stages of granary weevils (*Sitophilus granarius*) and minimum damage to grain quality. Moisture contents, however, are critical for long-term storage because germination of seeds decreased below 90 % when wheat grains were stored at 20°C under vacuum (0.5 bar) at m.c. of 14 % or higher. At higher temperatures this deterioration can be expected in even shorter storage duration. In order to avoid excess plastic waste, vacuum bags should be resealable. An alternative could be rigid structures. A project in the Kili-mandjaro region of Tanzania could provide first results on improved grain storage at farmer's level. So far, there are no ready solutions for good storage from industrialised cooler climates available because proper stored product protection has been an utterly neglected topic for decades due to the comparatively low market value of durables. Climate change, political unrest and increased migration may soon increase demand and market value and we better be prepared.

**Keywords:** Insects, moisture content, seal, storage, vacuum

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## Pineapple Processing in Central Uganda

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Pineapples, like many fruits, are highly perishable and require either immediate consumption or processing and/or refrigeration for later consumption. The perishability of fruits leads to high post-harvest losses (over 50% in Uganda). To improve pineapple shelf life and quality, four major processes are being employed in Uganda: processing into juice, wine, local drink (*munaanansi*), and dry products.

Our research assesses each of the processes to determine current practices in relation to energy and water utilisation, and fruit wastages. The objective is to better understand the present state so to guide resource optimisation, efficiency, and sustainability. Here we present results from studies on drying and *munaanansi* production in central Uganda for data collected (Nov 2016 - March 2017) within three districts (Kampala, Wakiso, and Kayunga). One drying company/cooperative was selected from each district. Modern hybrid dryers are employed by companies selected in Kampala and Wakiso while the Kayunga Cooperative owns ordinary solar thermal dryers. The Kasangati, Wakiso Company runs dryers on solar, mains, biomass, diesel, and petrol, while the Kawempe, Kampala Company runs on mains and biomass. The average inlet and exit temperature for one drying unit in Kasangati is 69.50°C and 47.11°C respectively, while the inlet and exit for one drying unit in Kawempe is 118.26°C and 59.20°C respectively. Relatedly; the average inlet and exit temperature for dryers owned by Kanguzumira Cooperative is 44.20°C and 45.50°C respectively. On average; Kasangati Company requires 10.89 kWh electrical energy and 2.48 kg of biomass to produce 1 kg of dry pineapples, while the Kawempe Company requires 3.07 kWh electrical energy and 3.48 kg of biomass to produce 1 kg of dry pineapples.

*Munaanansi* production is generally individual/family business; so six individual / family *munaanansi* producers were selected from Kampala where the drink is most popular. Firewood and charcoal are the main fuels while pineapples / pineapple peels are main raw materials. On average; 0.20 kg of pineapples / peels, 0.21 kg of biomass, and 1.04 L of water produce 1 L of *munaanansi*, yielding 0.15 kg of waste. Great potential for the optimisation of energy, water, and pineapples exists in these processes.

**Keywords:** Biomass, dryers, *munaanansi*, optimisation, perishable, solar

## On-Field Assessment of an Innovative Solar Powered Milk Cooling System in Tunisia

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Farmers in rural areas often lack on-farm storage and cooling possibilities which affects negatively the quality of their products. In the case of raw milk, a rapid cooling within the first two hours after milking is necessary for its preservation. In warm regions where milk cannot be cooled down, the risk of the milk rejection increases causing economical losses to farmers and milk collectors.

The University of Hohenheim in Germany has developed a solar milk cooling system. The technology is based on the use of 40 liters' conventional milk cans with a special designed ice compartment and removable insulation. The ice is produced by a solar powered freezer able to adapt to solar radiation with the help of an adaptive control unit. The concept allows cooling down up to 60 liters of milk by using ice as cooling medium.

In order to test the innovative system on the field, 10 milk cooling units were installed in 7 small farms in two regions in Sidi Bouzid, Tunisia.

Thermal milk cooling behaviour and transport times were tracked. Moreover, the milk quality of both cooled and uncooled milk was tested for morning milk at its arrival to the collecting centre. Furthermore, the possibility of using the system for overnight storage of evening milk was likewise assessed.

The results obtained from the different experiments showed that the temperature of the milk in the insulated cans decreased from an initial temperature of 35°C to less than 15°C in the first two hours. For the overnight storage, the milk was delivered to the collecting centre with a temperature of 8°C. The cooled milk had a higher quality compared to the uncooled milk which presented a bacteria growth of up to 4 times higher than the cooled sample. Milk stored overnight with the presented system was accepted by milk collecting centres opening for new business models for farms where milk is only picked up once a day. The results showed the capability of the system to enable farmers to access to small-scale refrigeration and increase their income while positively contributing to rural sustainability.

**Keywords:** Assessment, dairy farm, innovation, milk quality, on-farm cooling, solar energy

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## Utilisation of Different Types of Natural Dye Source as a Smart Packaging Indicator to Detect Fillet Damage of Chicken Meat During Storage

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This study aimed to determine the use of various types of natural dye as an indicator of smart packaging to detect chicken fillet damage during storage, to know the effectiveness of the use of natural dye as smart packaging indicators, and to determine the colour change that occurs in the indicator film. This research used an explorative design, with two factors: either storage at room temperature or storage in a freezer, and three different additions of natural dye extracts on the indicator film: “rosella” (*Hibiscus sabdariffa*) flower petal extract, “mangosteen” (*Garcinia mangostana*) peel, and extracts of “senduduk” (*Melastoma malabathricum*) fruits.

The results showed that the indicator film with the addition of anthocyanin extract was able to detect chicken fillet damage occurring during room temperature storage as indicated by the colour change on the indicator film. At room temperature storage, all three extracts showed a change in colour of the indicator film. However, meat deterioration under room temperature was best observed with the indicator film treated with “senduduk” extract; colour changed from °hue 351.29 (red-purple) value to °hue 41.53 (red) after 6 days at room temperature (with observations on day 1, 3 and 6). Measured pH value changed from 4.50 to 7.17, total anthocyanin content from 7.84 to 1.34 mg L<sup>-1</sup>, at day 1 and day 6, respectively. The film thickness used ranged from 0.11 to 0.23 mm.

**Keywords:** Fillet of chicken meat, indicator film, natural dyes, smart packaging

## The Neglected Governance Challenges of Agricultural Mechanisation in Africa – Insights from Ghana

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After decades of neglect, agricultural mechanisation is back on the agricultural development agenda in Africa. Taking the mechanisation efforts of Ghana as an example, this paper analyses the governance challenges involved in government and private sector efforts to promote mechanisation in smallholder-based farming systems. In Ghana, the government has been importing tractors for individual farmers at subsidised prices as well as setting up Agricultural Mechanisation Service Centres in almost all districts. The paper aims to analyse the governance challenges associated with such mechanisation strategies. Applying the agricultural innovation system approach, this paper develops a framework for identifying institutional bottlenecks and governance challenges related to mechanisation. A combination of qualitative empirical methods, including the Net-Map technique (a participatory mapping tool), was used to apply the framework. The evidence collected shows that mechanisation is constrained by missing institutions that would be required to ensure adequate training of tractor operators and technicians to service the tractors. Apart from such deficits in skill development, lack of access to credit and access to spare parts were major constraints. In addition, exchange rate fluctuations and impeding custom practices hindered a stronger private sector involvement in mechanisation. Government imports of tractors and machinery were found to be influenced by political interest and elite capture.

Some of these problems already led to the failures of past state-led mechanisation efforts in the 1950s and 1960s. The findings suggest that instead of focusing on the supply of subsidised machinery, the government could be more effective by strengthening the agricultural innovation systems for agricultural machinery to support emerging private sector initiatives.

**Keywords:** Africa, agricultural innovation system, agricultural mechanisation, governance challenges, smallholder farming

## Thermal Modelling of a Solar Tunnel Dryer for Drying Parsley (*Petroselinum sativum*)

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Commercialisation of horticultural species is widespread in Colombia. Drying of parsley leaves (*Petroselinum sativum*) is increasingly common due to its medicinal and culinary properties. Furthermore, essential oils of parsley are used in perfumery, cosmetics and soaps. If the drying of parsley leaves is done under controlled conditions, restrain the reproduction of undesirable microorganisms, so the quality of the product is kept.

A thermal model is formulated to test the efficiency of the tunnel dryer "Hohenheim". This dryer was developed in the mid 80s at the University of Hohenheim, Germany. This dryer is usually composed of a collector, a drying chamber and a photovoltaic panel. In this study, the dryer was improved using a thermal model. The method used to develop this thermal model was the finite volume method in which an energy balance was made for each dryer section. The set function conditions for the dryer were a variable temperature between 30 and 60°C, a relative humidity of the ambient air between 62 and 86% HR, and an average solar radiation of 600 W m<sup>-2</sup>. The initial moisture content of the parsley was around 78% (w.b.). The model was based on Ficks law on thin-layer diffusion. The following coefficients were used: an activation energy value of 56.3 kJ mol<sup>-1</sup> and a constant in Arrhenius equation equal to  $3.67 \times 10^{-2}$  m<sup>2</sup>/s. The results allow predicting the drying ratio of parsley leaves. Furthermore, coefficients for the relative humidity, as well as for the air and product temperature were calculated in relation with the dryer geometry and the product placement in the dryer. Finally, efficiency values of the collector, the dryer chamber and total efficiency are shown.

**Keywords:** Drying of parsley leaves, energy balance, thermal modelling, tunnel dryer

## Effect of Drying Air Temperature and Slice Thickness on the Colour, Texture and Rehydration Parameters of Dried Beef

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There is an increasing demand for beef in sub-Saharan Africa; driven by an increase in population growth and disposable income. However, beef is highly perishable and its commercialisation by the pastoral communities of Kenya is challenging due to high temperatures and the absence of cold chain. Sun drying has been done for many years to preserve meat during excess supply. However, with an increasing demand for high quality dried products, solar drying is gaining a lot of interest. Therefore, in order to optimise the drying process under tropical conditions, information on dried product quality in conditions close to those encountered in the real processes is needed. The objective of this work therefore, was to determine the effect of drying temperature and slice thickness on the physical quality of dried beef.

Fresh beef was dried in a cabinet dryer “Hohenheim HT mini” at 30–60°C air temperatures and 0.25–1.0 cm slice thickness. Air flow was generated by a fan operating at 24 V and thin layer drying done to 20 % moisture content (dry basis). L\*(lightness), a\*(redness) and b\*(yellowness/blueness) colour measurements were done using a colorimeter (Minolta Chroma Meter CR-200). The rehydration ratio (RR) was calculated as the ratio of weight after to weight before immersion in a hot water bath (100°C for 10 min). Texture measurements were done using Volodkevich bite jaws (HDP/VB\*) fixture of a TA.XT.plus Texture Analyzer. Drying time ranged between 2.5 and 30 h for different samples. There was a significant decrease ( $P \leq 0.05$ ) in the L\* a\* and b\* values with increase in temperature and beef thickness. The RR was higher ( $P \leq 0.05$ ) at 60°C for samples with 0.5–1.0 cm thickness and decreased ( $P \leq 0.05$ ) with increase in beef thickness. The firmness values increased ( $P \leq 0.05$ ) with increase in temperature from 30 to 50°C then decreased at 60°C and were significantly lower ( $P \leq 0.05$ ) at 0.25 cm beef thickness. In conclusion; with view of drying process optimisation with respect to time and physical quality of beef, heating temperature zone of 60°C and a lower meat thickness was recommended.

**Keywords:** Cabinet drying, colour, dried beef, rehydration, texture



## **Ziplock Packaging Film for Reducing Quantitative and Qualitative Losses of Vegetable Amaranth Leaves (*Amaranthus cruentus* L.)**

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Recently, the demand for African indigenous leafy vegetables (AIVs) such as vegetable amaranth (*Amaranthus cruentus* L.) has been steadily increasing amongst rural, peri-urban and urban dwellers in developing countries due to their high nutritive and medicinal values. Vegetable amaranth has a great potential in creating job opportunities especially for youth and women. However, it suffers significant postharvest losses, owing to its fast rate of deterioration. To address this, a study was conducted to determine the effect of ziplock packaging film bags on the shelf life and nutritional quality of vegetable amaranth leaves cv. Madiira. The vegetable was grown under greenhouse conditions (15 – 27°C, 60 – 80 % RH). Eight weeks after planting, leaves were harvested and either packed in ziplock bags or unpacked (control). The leaves were stored for 4 d (evaluated at 0, 2, and 4 d) and 7 d (evaluated at 0, 2, 4 and 7 d) at 20°C (65 % RH) and 5°C (85 % RH), respectively. The parameters studied were fresh weight loss, carotenoids (lutein, lycopene and  $\beta$ -carotene), chlorophylls, and selected mineral elements (P, K, Ca, Mg, Fe and Zn). Ziplock packaging film bags resulted in lower weight loss (0.2 – 1.5 %) compared with the control (0.4 – 3 %), with the effect being more pronounced at 5°C. The carotenoid contents were significantly higher in leaves under ziplock packaging film compared with control leaves; the results being comparable in both storage conditions. Ziplock packaging film helped to retain chlorophyll content and thus leaf colour during storage with the effect being more pronounced at 5°C. Mineral elements were variedly affected by using ziplock bags depending on storage temperature and duration. The results obtained showed immense potential of reducing postharvest loss by improving shelf life and quality attributes of vegetable amaranth leaves using ziplock packaging film bags.

**Keywords:** African indigenous leafy vegetables, *Amaranthus* spp., food loss, packaging film, vegetable quality

## Determinants of Technical Efficiency of Dairy Processing Firms in Southern Brazil

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Historically the dairy industry in Brazil has been mainly focused on the domestic market and minor efforts were made in order to increase the productivity, technology adoption or professionalisation of producers and processors. In recent years the internal demand for dairy products increased significantly with the purchasing power of Brazilian consumers. Multinational dairy processors installed processing plants in the country, but also the high quantities of imported good quality and cheap dairy products threaten the national industry. Therefore in the largest dairy production area in southern Brazil, national dairy processing companies are facing challenges to organise the supply chain and to improve their performance in this very competitive sector. In order to design new policy recommendations to improve the performance of the dairy industry in southern Brazil we investigate productivity and the determinants of technical efficiency (TE) of these dairy processing firms. Data on firm structure, management capacity, institutional choice and policy support of 244 dairies are analysed. A parametric production frontier is estimated (using the Bayesian approach) and the determinants of technical efficiency are computed. An overall efficiency of 79 % indicates margin for increasing the outputs by 21 % using the same inputs. Economies of scale were also detected. According to the results less idle processing capacity contributes to improve efficiency as expected. Having more organisational employees (administrative, quality control, R&D, farmer consultancy) makes companies more efficient. Investments in growth and modernisation in the last 5 years decrease the efficiency of the companies. This result could be explained by high learning costs; high interest rates over loans/credits and/or delay in getting positive effects. A larger portfolio of products increases the efficiency. Contradicting the transaction costs theory we found that cooperatives are more efficient. The reason could be that the organisation matters more in Brazil than in other places for the dairy sector, or the social capital of cooperatives play an important role. Through our results it's possible to suggest important management advices to companies but also public policies to the Brazilian government in order to booster the growing dairy sector.

**Keywords:** Brazilian dairy sector, dairy cooperatives, dairy processing firms

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## Improving the Date Production Chain in the Moroccan Oases through Small Mechanisation Inputs to Support the Governmental Development Strategies

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Moroccan oases as other Saharan oases are a highly artificial ecosystem that has proved to be capable of sustaining agriculture under arid climatic conditions for centuries, though it has suffered a strong degradation process during the last decades. This is due to a complex phenomenon linked to socio-economic, political and climate changes, that has brought traditional oasis agriculture to lose its relevance, consequently putting its complex environment in serious danger. The most important factors of degradation of the agricultural system are: land and water scarcity, salinity, silting and the negative impact of various pests and diseases (the most dangerous of which is Bayoud). Small farmers are the most important resource for the surviving of the oasis ecosystem but, on a socio-economic point of view, oasis dwellers, especially the younger ones, tend to search for better livelihood opportunities elsewhere, with consequent loss of traditional knowledge and availability of labour for all agricultural operations.

Date palm cultivation is the most important crop in this environment but date production faces several problems along the whole chain (field operations, storage, processing and marketing phases) and the oldest groves are abandoned for new intensive plantations with consequent endangering of biodiversity and genetic heritage.

In the last years, the Moroccan Government launched development programs such as the Programme Oasis Sud and the Plan Maroc Vert, with the goal to restore a sustainable oasis ecosystem. The main focus of these interventions is on date post-harvesting operations, improving storage, transformation and marketing capability of farmers and cooperatives, sustaining rural development through market improvement, but most constraints of field operations are still unsolved.

This work reports an analysis that has been carried out on Moroccan oases farming system and outlines the main constraints proposing some possible mitigation interventions, based on the introduction of small mechanisation inputs along the production chain, especially for the most dangerous aerial operations such as pollination, harvesting and pruning. Interventions are designed to support and integrate the implementation of the governmental strategies as well as other interventions (e.g., of the international cooperation agencies), allowing to create a network of practice and to build partnerships.

**Keywords:** Date palm, light mechanisation, small scale, traditional farming systems

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## Determination of the Design and Selection Characteristics of Potato Diggers for Animal Draught in Colombia

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With the aim to select the main components of potato diggers that best satisfy the technical characteristics of production of the small farmers of the Altiplano Cundiboyacense Region in the Western Mountains in Colombia, an assessment of the main features that govern the design and behaviour of such machines was made. For this, the equations of the performance of the main mechanisms of the machines were established and therefore the characteristics that should be measured in field and laboratory. The measured characteristics in the potato fields were: density of the soil mass, geometrical configuration of the tubers distribution *in situ*, geometric configuration of the ridges in the field, cohesion and friction coefficient of the soil in the ridge, friction coefficient between soil and metal, penetration resistance of the soil in the ridge, weights of potatoes and stems at the harvest time, soil moisture content at the harvest season, compressive strength of clods of soil, and size distribution of clods of soil in the ridge.

With these features, some recommendations for the size and behaviour of the cutting blade, the drive units and the crumbling and separation units were formulated. The study allowed finding the size ranges of the components specially for animal traction machines but also for machines for tractor. In general the dimensions do not vary much from those of commercial machines. The cutting blade must have 690 mm length and 1070 mm width for tractor machine and 980 mm length and 875 mm width for animal draught, its cutting angle should be between 50 and 74°, and slope of 25° for tractor pull and 18° for animal draught. Tires should be used for the driving unit that goes over the ridge. For separation of clods the conveyor belts with rods are the best option, with 1500 mm length for tractor machines and speed so low as 0.94 m s<sup>-1</sup>.

**Keywords:** Animal draught, hillside agriculture, potato diggers

## Use of Computational Fluid Dynamics Modelling Tool for Assessment of Airflow Distribution in a Double-Pass Solar Drier

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Nowadays solar driers become one of the most promising technologies, which can process significant quantities of products under adequate hygienic conditions and with reasonable costs. Furthermore, the majority of solar driers are fully independent to conventional sources of energy. The new model of indirect forced convection solar drier called double-pass solar drier (DPSD) was designed at the Department of Sustainable Technology at the Faculty of Tropical AgriSciences at the Czech University of Life Sciences Prague, a few years ago. One major drawback of DPSD is the spatial heterogeneity of air distribution in the drying chamber, that has influence on the uniformity of the drying process. Thanks to the technological advancement in computing, there is a relatively new and accessible method of how to assess the distribution of airflow. CFD (Computational Fluid Dynamics) which is thanks to a number of known equations a valuable tool for engineering and analysis of solving complex fluid flow by addressing heat and mass transfer phenomena. CFD is already used for re-designing of tray driers and batch type driers that are producing high quality of dried products. The current work will present how the incorporation of CFD helps to assess the distribution of airflow in a solar drier, specifically in a drying chamber of DPSD. The methodology is consisted of two parts: the experimental analysis, which measured the speed of airflow, temperature and humidity as an input data, and the modelling of airflow with the use of CFD software, which is consisted of defining boundaries and inlet/outlet values and phenomena. The results will show us, how the airflow is distributed inside the drying chamber through the three-dimensional model and vectors or two-dimensional model and contours. Further, the results, may address flaws and will propose appropriate improvements in the construction of the existing solar drier to enhance drying efficiency and increase the final product quality.

**Keywords:** Airflow, CFD, solar driers

## **Hoe, Bullocks or Tractor for Ploughing, Why Do Farmers Choose What?**

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In Ghana 65 % of the population is active in agriculture, but even with that there is a strong lack of labour. Ploughing is one of the main labour tasks in the cropping year. Farmers in northern Ghana plough their land by hoe, with draft animals (mostly bullocks) or mechanised (mostly tractors).

This research is explaining why farmers chose which ploughing technique, as the three techniques are often used by different farmers in one and the same village.

The research was conducted interviewing 50 farmers over two communities in two different regions. Various experts active in agriculture were also interviewed.

The farmers were asked about the in- and out-puts of all their fields, labour figures were collected, as well as data on the perceived socio-economic performances of the techniques. Farmers owning bullocks were asked to quantify all their costs. All farmers were asked to motivate their answers. Experts were interviewed to ratify, steer and interpret the farmer interviews, as well as for giving contextualising information.

The lack of bullocks and tractors, in northern Ghana, causes difficulties to plough all the land on time. Especially for those having fewer resources to pay for the service it is a problem. Delay in ploughing leads to a delayed planting, which in these very time sensitive cropping zones leads to substantial yield losses. But ploughing is not only a very crucial and expensive activity it also requires a lot of labour (7 % of the total farm labour, for maize fields ploughed with bullocks).

Even though there is disagreement on the benefits and disadvantages of the techniques, most farmers see tractors as being the future.

But even so farmers still would like to buy bullocks if they would have the money. This because of the high prices for tractor services and their delayed arrival, a problem which they don't expect to be solved soon.

**Keywords:** Bullocks, labour figures, perception, ploughing, tractor

## Participative Development of a Top-Lit-Up-Draft Reactor for Simultaneous Cooking and Biochar Making

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In many countries biochar is being used as a valuable soil amendment improving the soil structure and nutrient holding and exchange capacity on a long-term base. Up to date many different technical devices with different capacities and technical qualities have been developed to produce the required biochar. The material used to feed these devices ranges from forest products to agricultural residues like maize cobs.

The present study describes the participative and gradual adaptation of an existing 200 litre Top-Lit-Up-Draft (TLUD) reactor (Pyrolyser) in Tanzania that as a first version was solely used for biochar production. After reflective stakeholder-scientist consultations it was sought to find a solution sufficing local demands of adding a cooking component to the biochar making by synchronising both. This device should be economically and technically feasible at minimal costs in Tanzania. A new reactor was designed to meet the requirements. Iteratively, modifications and test trials of the existing TLUD reactor design were done, and then the new reactor and its operating protocol were obtained and tested. The results showed that the new reactor, on average boiled 4.5 litres of water at 93°C within 44 minutes. Also, it produced 0.30 kg of biochar per kg of cobs fed, totalling 6.0 kg per reactor minimal filling. The reactor average operating temperature was 159°C. The initial cost (€ 68) of acquiring the new reactor may not be affordable for single households in rural area but for stakeholder groups using it together. Household's saving which may be gained from commercialising the new reactor is assumed to amount (€ 37)/month. Apart from these promising parameters of the new reactor, more research is needed to unleash the full potential of its applicability in rural areas.

**Keywords:** Biochar, cobs, cooking, energy, fertiliser, firewood, household, reactor, TLUD, top-lit-up-draft

## Effects of Age, Storage Temperature and Duration on Total Phenolics, Flavonoids and Antioxidants in African Nightshade

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African nightshade (*Solanum scabrum*), a leafy vegetable plays a great role in food security and livelihood in sub-Saharan Africa. The vegetable is highly nutritious and contains phenolics and flavonoids, major sources of antioxidants highly valuable in human diet. The phenolics and flavonoids have other important properties such as, anti-inflammatory, anti-microbial, anti-allergenic and anti-thrombotic. The study aimed at analysing the secondary metabolites during development, storage at 5°C and 80–85 % relative humidity (RH) and room temperature (RT) (20–25°C) at 55–60 % RH, for a duration of 0, 2, 4, 6 and 8 days. The total phenolic contents (TPC) were analysed using Folin-Ciocalteu method and were expressed as Gallic acid equivalents. The calorimetric method was done for flavonoids followed by spectrophotometric absorbance at 510 nm and 415 nm, the results were expressed as catechin and quercetin equivalents. TEAC assays were conducted for antioxidants. The TPC, flavonoids and antioxidants were higher at 90 days after planting (dap) ( $12.6 \pm 1.7 \mu\text{g mg}^{-1}$ ,  $24.1 \pm 2.8 \mu\text{g mg}^{-1}$  and  $0.45 \mu\text{g mg}^{-1}$  of dry weight respectively). There was a significant decline of these three after 4, 6 and 8 days storage at RT. After 8 days of storage at RT, the TPC and flavonoids declined to  $1.1 \pm 0.1 \mu\text{g mg}^{-1}$  and  $2.9 \pm 0.9 \mu\text{g mg}^{-1}$  respectively. There was no significant decline at 5°C storage up to 8 days. Plant age, storage duration and temperature affects TPC and flavonoids and it would be recommendable to store nightshade at low temperatures to avoid losses. Further experiments are going on to determine development stages with optimal secondary metabolites and storage longevity.

**Keywords:** African nightshade, days after planting, flavonoids, phenolics, temperature



## An Optimised Solar Camel Milk Powder Processing Plant for Rural Arid and Semi-Arid Regions

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Kenya's camel milk industry contributes significantly to the economic and nutritional safety of the population located in the arid and semi-arid areas (ASALs). Due to the inadequacy of preservation technologies, the production and consumption of milk are limited to this group. Processing the milk into powder is one approach for the extension of shelf life. This process is very energy intensive. The exemption from Value Added Tax on solar products by the Kenyan government coupled with high solar irradiation in the region provides an alternative energy source. This study, evaluated the feasibility and design of an energy efficient and solar assisted milk processing plant for decrease of post-harvest losses, greenhouses gas emission reduction and efficient energy utilisation. The reference values used in the computation of the energy consumption of the milk powder and butter were based on prior fieldwork. Initially, the process was characterised and optimised, the energy targets redefined the energy targets and multiple solar integration points were analysed. The analytical tools included: mass & energy balance; Pinch analysis, simulation of solar thermal and analysis of the economic feasibility. The analysis showed that a significant amount of cream is produced during milk powder processing line, and to limit its wastage, the excess cream is channelled for butter processing. In optimising the process, a resequence design was the most economical, having the energy requirement for the processes decreases by approximately 46.1 %. This required an increased investment cost for heat exchanger integration. Moreover, the amount of water used decreased by approximately 50 % per litre of processed milk. For processes below 90°C that utilises hot water, which is approximately 85.5 % of the total energy demand, could best be met with evacuated tube collectors. For chilling, cooling and mechanical processes solar photovoltaics was utilised. For the highest energy demanding process, spray drying, the air was first preheated by exhaust air from the process, then preheated to 90°C by solar thermal and finally indirectly heated by a fuel oil boiler. In conclusion, an optimised hybrid system of fuel oil and solar energy is proposed for the ASAL milk powder processing plant.

**Keywords:** ASALs, butter, process optimisation, solar thermal energy

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## Optimisation of Enzymatic Treatment for Cassava Root Peeling

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This study examined the optimisation of enzymatic treatment of cassava roots for improving the peeling process. The peels of the cassava roots (purchased from a local market in Stuttgart) were used. A mixed enzyme was applied on the cassava root peels. The operational parameters were temperature (40°C, 45°C, 50°C, 55°C and 60°C), pH (3.5, 4, 4.5, 5, 5.5), incubation time (1 hour, 2 hours, 3 hours, 4 hours and 5 hours), and a dose of enzyme (0 ml, 1.25 ml, 2.5 ml, 3.75 ml and 5 ml). Response surface methodology by the central composite design was applied to optimise the enzymatic treatment of cassava peels. The sugar content (saccharose, glucose, galactose and mannose) of the applied enzyme solution, in which the cassava peels were incubated, was measured using HPLC with refractive index (RI) detector. The glucose content was determined as a response factor for screening the enzymatic treatment efficacy assuming that breakdown of cellulose and hemicellulose will result in an increase of glucose. After 30 runs of enzyme treatment in the central composite design, multivariate correlation of the glucose content was established through reduced quadratic model with  $R^2 = 0.9543$  and MAPE=1.08. Results showed glucose content was significantly affected by the enzyme dose and incubation time. Under optimal conditions (pH of 4.5, temperature of 49.8°C, incubation time of 3.8 hours, and 3.75 ml mixed enzyme), the maximum glucose content was 21.2%. Through the maximising glucose content, the application of mixed enzyme has increased the softening of the cassava peels. The results suggest that the enzymatic treatment could be used to improve the peeling process by increasing loosening the cassava root peels.

**Keywords:** Cassava root peeling, central composite design, enzymatic treatment, glucose, optimisation

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## Gender Implications of the Introduction of Forage Chopper Machines

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The mechanisation of agricultural labour processes is often associated with a decreased work burden and improved production for small-scale farmers. However, empirical evidence suggests that consequences of mechanisation may vary for men and women within households or communities. Technological interventions are known to interact with gender norms, gendered access to and control over resources and decision-making. Therefore, to fully understand impacts of mechanised production gender analysis is required.

In an effort to curb the labour burden and amount of time consumed in manual feed processing among livestock keepers the USAID-funded R4D project Africa RISING introduced forage chopper machines in seven villages in Babati (Northern Tanzania). In 2016 – one year later – a team of social scientists evaluated the gender implications of the new processing practices through focus group discussions, matrix scoring, linkage diagrams and a survey. Male and female respondents were selected from among the farmers' groups that were formed for the management and use of the chopper machines.

First findings show that the technology reduces in particular women's labour burden and decreases the time needed for livestock feeding. At the same time, additional labour and cost implications of operating the machine impeded actual technology use for some farmers. Access to the forage choppers is influenced by various factors - among others membership and gender dynamics in farmers' groups. Men tend to operate machines more frequently, which they in part justify by claiming "lower technical skills" and "lower physical strength" of women. On the other hand, the benefits from improved feeding through the sale of milk and eggs have allowed some women to become financially more independent. The results of this study will not only inform the R4D project's further livestock work, but will also feed into the ongoing gender and mechanisation debate.

**Keywords:** Feeding, gender, livestock, mechanisation, Tanzania

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## Drying Kinetics of Purple Flesh Sweet Potato Grown in Malaysia

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Sweet potato is a very important crop for people in Southeast Asia because of its abundant source of carbohydrate. Currently, purple flesh sweet potato (var. Kedudut) has been introduced in Malaysia due to its health benefit properties. Additionally, the crop is highly perishable which needs to be preserved by processing into dried form. The dried sweet potato can be potentially used in various products such as pre-mixed drinks, baby food and other health supplements. This draws the attention of the importance of drying in the processing of sweet potato. The aim of this paper is to discuss the drying kinetics of purple flesh sweet potato at different temperatures and its relation with effective moisture diffusivities and activation energy. Sweet potato was dried until the moisture content reduced to approximately 10 % by using cabinet dryer at 50°C, 60°C and 70°C at constant air velocity of 0.25 m s<sup>-1</sup>. Several mathematical models such as Wang and Singh, Henderson and Pabis, Lewis, Exponential decay and Page equations were used to describe the moisture ratio during drying process. The result shows the best fitting model to describe the drying curves of sliced purple flesh sweet potato is exponential decay equation for all drying temperatures. The effective diffusivity of sweet potato at 50°C, 60°C and 70°C drying temperature were in the range of  $1.46 \times 10^{-9}$  to  $3.39 \times 10^{-9}$  m<sup>2</sup> s<sup>-1</sup>. The activation energy for the drying process was found to be 35.102 KJ mol<sup>-1</sup> which is comparable with the reported values of various food materials.

**Keywords:** Dried sweet potatoes, drying, drying model, moisture content

## Integrated Postharvest Technologies for Improved Postharvest Handling of Mango

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Food and nutrition security poses a major challenge to sustainable development in sub-Saharan Africa. Abundant intake of fruit and vegetables is essential for human health and, particularly, mango is a good source of phytochemicals which are recommended to be included in the daily diet due to its high amounts of carotenoids potentially serving as Vitamin A precursors. Consequently mango fruit consumption can contribute to eliminating Vitamin A deficiency, however, mango fruits are highly perishable due to limited alternatives in postharvest technologies. In sub-Saharan African countries, storage and ripening of mangoes is carried out, but continues to be a challenging problem experienced by small scale farmers. Large quantities of mango produced are transported with trucks without cold chain or mechanical protection or recommended postharvest treatment. This results in significant amount of quantitative and qualitative losses, due to mechanical damages, over maturation, and postharvest diseases before reaching the consumer. However, wide range of existing food processing and postharvest technologies is expensive and often not accessible or adaptable to sub-Saharan African countries. Therefore, there is an urgent need to develop appropriate affordable technologies that can empower the smallholder farmers to preserve the quality of produce, support the food security, and generate income via horticulture by reducing postharvest losses of mango. Although, refrigeration is generally recognised as a key tool for successful marketing of perishable products, such sophisticated cooling systems are unavailable or non-existent for African smallholder farmers due to financial constraints and lack of electric power. The aim of the present study was the analysis of the effect of storage conditions (cooling and low oxygen limit) on the carotenoids profile measured by means of high pressure liquid chromatography as well as non-destructively by means of diffuse reflectance spectroscopy. Results provide the information on the positive effects on the nutritional value of the mango fruits stored with the new technology. Moreover, such technology can easily be adopted by small scale farmers to preserve the quality of mango fruits and contributing to food and nutrition security.

**Keywords:** Carotenoids, food security, mango, nutrition, postharvest technology

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## Enhanced Food Security via Adoption of Improved Cooking Stoves and Local Wood Plantations in Tanzania

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Firewood supply is a severe challenge in degraded and deforested areas of Tanzania which negatively affects the livelihoods of rural dwellers. The majority of rural households cook with energy-inefficient traditional three-stone-fire-stoves. Especially women and children who are mainly responsible for firewood collection spend substantial time to collect firewood which increasingly compromises their available time for agricultural activities. Our analysis showed that Improved Cooking Stoves as well as enhanced planting of on-farm trees realise time savings and can improve agricultural landuse management schemes in semi-arid areas of Tanzania.

Improved Cooking Stoves were implemented in a participative way within the case study villages. The quantitative and qualitative field-based stove performance test “Kitchen Performance Test,” demonstrated that the implemented Improved Cooking Stoves reduce the demand of firewood by almost 30 % and decreased cooking time by around 20 % compared to the traditional three-stone-fire-stoves. Farmer’s local knowledge - here on loam construction - supported the sustained adoption and dissemination process of locally manufactured two-pot Improved Cooking Stoves which provided additional available time for agricultural activities.

In addition, on-farm wood plantations (either as bordering or intercropped plantations) close to homesteads reduce the number of walks to collect firewood and therefore save time. Nevertheless, tree husbandry faces several challenges caused by environmental as well as anthropogenic factors. In a next step, trial plots will be established to quantify yield enhancements induced by tree / crop integration. By providing evidence-based results on the positive effects of tree plantations on agricultural landuse management practices as well as on food-security in semi-arid areas of Tanzania, rural dwellers are further incentivized to engage in tree planting.

Capacity building and creation of local know-how on constructing and using Improved Cooking Stoves as well as tree husbandry are central for the realisation of socio-economic benefits. It is important to monitor the implementation of Improved Cooking Stoves and the adoption process of planted trees regarding slow-down of dissemination rates or incomplete usage practices. The identification of bottlenecks for sustained adoption is central for endurance and enhanced dissemination of the two innovation strategies which provide substantial “free” time for agricultural activities.

**Keywords:** Agricultural yields, improved Cooking Stoves, intercropping, on-farm tree plantation, Tanzania

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## **Effect of Improved Stoves on Wood Consumption and Particulate Matter and Carbon Monoxide Production**

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In rural Central America the dominant source of fuel for cooking is biomass. This practice triggers two significant problems in the region: 1) health issues for users and household members; and 2) deforestation caused by the quantities of wood required to maintain the practice. Sustainable Harvest International, a USA-based non-profit organisation, has been developing and promoting different models of efficient wood-conserving stoves in Panama, Belize, Nicaragua and Honduras since the year 2000. In collaboration with EARTH University (Costa Rica) and Aprovecho Research Center (USA), a systematic evaluation of two improved stove models – ‘Damak’ in Panama, and ‘Mani’ in Honduras – was performed. The evaluation used a state-of-the-art portable Indoor Air Pollution Meter (IAP) 5000 series. Using the IAP, the collaborators took 30-minute air samples of stoves at maximum cooking temperatures. The sample consisted of 40 improved stoves and 34 traditional stoves being measured in Honduras; in Panama the sample comprised 24 improved stoves and 22 traditional ones. The results indicated that in comparison to their traditional counterparts, the improved stoves consumed 58 % less wood and an impressive 278 % less particulate matter, as well as an astonishing 8137 % less carbon monoxide. In conclusion, adapted, improved stoves made from local materials are proving to consume less wood and produce better air quality for rural families in Central America. Larger samples examining field conditions and measurements under laboratory conditions are needed to corroborate the significantly large differences. However, this first systematic assessment gives us enough information to affirm that these locally developed stoves are an inexpensive solution that is improving the lives of tens of thousands of rural families in the region.

**Keywords:** Biomass, Central America, improved stoves

# Agrobiodiversity and nutrition diversity

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## Oral Presentations

- HABTAMU S. ARAGAW, OMARSHERIF MOHAMMED JEMAL, JULIAN PHILPP WALD, DONATUS NOHR, DANIEL CALLO-CONCHA:  
**Nutritional Potential of Underutilised Edible Plants in Agroforestry Systems of Yayu, Southwestern Ethiopia** 410
- FAITH ANGELINE MANDITSERA, PIETERNEL A. LUNING, VINCENZO FOGLIANO, CATRIONA M.M. LAKEMOND:  
**Contribution of Indigenous Edible Insects to Food Security in Rural and Urban Zimbabwe** 411
- SAHRAH FISCHER, THOMAS HILGER, JAN WELSCH, CATHERINE MEYER, IRMGARD JORDAN, GEORG CADISCH:  
**What Is Planted Is Not Eaten – Using Production Diversity to Link Agrobiodiversity and Dietary Diversity** 412
- JULIA BOEDECKER, FRANCIS ODOUR ODHIAMBO, CÉLINE TERMOTE, GINA KENNEDY:  
**Participatory Approach to Increase Dietary Diversity through Agricultural Activities and Nutrition Education in Western Kenya** 413
- ANDREA FONGAR, THEDA GÖDECKE, DAVIS MUTHINI, ANTONY ASETA, MATIN QAIM:  
**Delivery of Nutrition Education through Agricultural Extension: Evidence from a Randomised Trial in Rural Kenya** 414

## Posters

- JACOB SARFO, GUDRUN B. KEDING, JULIA BOEDECKER, ELKE PAWELZIK, CÉLINE TERMOTE:  
**The Impact of Wild Plant Foods in Reducing the Minimum Cost of a Nutritious Diet in Turkana, Kenya Using Linear Programming Modelling** 415
- SIRAWDINK FIKREYESUS FORSIDO, ALEMGENA AYANA, TEFERA BELACHEW, OLIVER HENSEL:  
**Fermentation and Addition of Malt to Improve Physicochemical and Sensory Properties of Complementary Foods Prepared from Starchy Grains** 416



- ANNA MANOUROVA, BOHDAN LOJKA, OLGA LEUNER,  
PATRICK VAN DAMME, ZAC TCHOUNDJEU, JAKUB HOUŠKA,  
ONDREJ PRIBYL:  
**Diversity and Nutritional Characteristics of *Garcinia kola*  
Heckel (Clusiaceae) in Southwest Cameroon** 417
- JOSIAH CHIVEU, MARCEL NAUMANN, ELKE PAWELZIK,  
KATJA KEHLENBECK:  
**Nutrient Composition of Guava (*Psidium guajava* L.) Fruits  
as Influenced by Soil Nutrients** 418
- TAFESE BOSHA BORKO, CHRISTINE LAMBERT, SIMON  
RIEDEL, HANS KONRAD BIESALSKI:  
**Dietary Diversity, and Nutritional Status of Mother-Child  
Pairs by Season in *Enset* Cultivating Areas of Southern  
Ethiopia** 419
- TIBEBESELASSIE KEFLIE, SARAH TRILLER, JULIAN PHILPP  
WALD, CHRISTINE LAMBERT, DONATUS NOHR, HANS  
KONRAD BIESALSKI:  
**Stinging Nettle (*Urtica simensis*): An Indigenous But Unrecog-  
nised Micronutrient Potential for Combatting Hidden Hunger  
in Ethiopia** 420
- BRENDAH WEKESA, MARY NGENDO, STEPHA MCMULLIN:  
**Food Security, Dietary Practices and Nutrition Status of  
Mothers/Caregivers and Children in Laikipia County, Kenya** 421
- HADIJAH MBWANA, JOYCE KINABO, CONSTANCE REIF,  
WOLFGANG STUETZ, STEFAN SIEBER, KHAMALDIN DAUD  
MUTABAZI, HANS KONRAD BIESALSKI:  
**Rural Agriculture for Improved Nutrition: Stakeholder  
Insights from Different Sectors in Tanzania** 422
- ADMASSU TESSO HULUKA, TECHANE GONFA ABEBIE,  
GUDRUN B. KEDING:  
**An Assessment of Household Dietary Diversity and Vegetable  
Consumption: Case Study of Smallholder Farmers in Yayu  
Biosphere Reserve, Ethiopia** 423
- MARIE KAMRAD, ANNA RÖHLIG, M. GRACIA GLAS, JOHNNY  
MUGISHA, ERNST-AUGUST NUPPENAU, IRMGARD JORDAN:  
**Diet Adequacy of Male Ugandan Farmers – A Cross-Sectional  
Case Study in Kapchorwa District of Uganda** 424
- VICTORIA GOWELE, JOYCE KINABO, CONSTANCE RYBAK,  
STEFAN SIEBER, KHAMALDIN DAUD MUTABAZI, NYAMIZI  
BUNDALA, HANS KONRAD BIESALSKI, WOLFGANG STUETZ:  
**Dietary Diversity and Micronutrient Status of School  
Children in Chamwino and Kilosa Districts, Tanzania** 425

<p>ELISABETH Y. PARKES, EDWARD KANJU, PHENEAS NTAWU- RUHUNGA, NZOLA-MESO MAHUNGU, FEMI AINA, ALFRED GILBERT DIXON, PETER KULAKOW, ROBERT ASIEDU, KINGS- LEY C. AKUWA, BAKARE MOSHOOD, AFOLABI AGBONA, BELLO R. ABOLORE, DEBORAH OLAOSEBIKAN, PAUL ILONA: <b>Mainstreaming Biofortification in Africa: A Contribution Towards Reducing Malnutrition and Hunger</b></p>	426
<p>ERICK MAINA, SAMWEL MBUGUA, LYDIAH WASWA, MICHAEL KRAWINKEL, ERNST-AUGUST NUPPENAU, IRMGARD JORDAN, ELIZABETH KAMAU: <b>Factors Influencing the Nutritional Status of Women of Reproductive Age in Teso South Sub-County, Kenya</b></p>	427
<p>KATHRIN MARIA DEMMLER, OLIVIER ECKER, MATIN QAIM: <b>Supermarket Shopping and Nutritional Outcomes: A Panel Data Analysis for Urban Kenya</b></p>	428
<p>ELIZABETH KUSIA, SEVGAN SUBRAMANIAN, CHRISTIAN BORGEMEISTER: <b>Community Perceptions, Practices and Knowledge of Insects for Food in Kenya: A Case of Saturniidae</b></p>	429
<p>RUBEN CASAS REATEGUI, ZBYNEK POLESNY, PABLO PEDRO VILLEGAS PANDURO, LUDVÍK BORTL, LUKAS PAWERA, RUBEN MANTURANO PEREZ: <b>Edible Insects Used by the Amerindians Shipibo and Ashan- inca of Ucayali High Basin in Peruvian Amazon</b></p>	430

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## Nutritional Potential of Underutilised Edible Plants in Agroforestry Systems of Yayu, Southwestern Ethiopia

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In Ethiopia, food and nutrition insecurity has remained a major issue since the great famine in 1984. Most efforts have been designed to increase productivity per unit area of land, but the potential of uncultivated plants remains untapped. This study aimed to explore the nutritional potential of underutilised fruits and vegetables in Yayu, southwestern Ethiopia. Group and key informant interviews along with laboratory analyses were conducted to assess the existence, level of exploitation and nutrient content of selected species. Proximate food composition, selected minerals, vitamins and anti-nutrient factors content determined using standard methods. A total of 94 edible plant species were found in coffee agroforests and home-gardens, out of which 40 were characterized as underutilised species. Finally, twelve edible species were selected based on their current importance and future production potential, whose proximate food composition, mineral and vitamin content were found to be significantly different ( $p \leq 0.05$ ). The leaves of *Amaranthus graecizans*, *Solanum nigrum* and *Portulaca oleracea* contained protein in the range of 15.62 – 19.26 g/100 g dry edible portion (EP); calcium 585.00 – 2065.00 mg/100 g; iron 24.14 – 91.19 mg/100 g and zinc 1.6 – 3.81 mg/100 g EP. The fruits of *Carissa spinarum* and *Syzygium guineense* contained energy values of 252.30 and 244.54 kcal/100 g EP, respectively, comparable to the average energy value for maize (278 kcal/100 g). In addition, *Syzygium guineense* had a vitamin C content of 330.72 mg/100 g fresh EP and *Rubus apetalus* had a beta-carotene content of 1.94 mg/100 g, making them a rich source of vitamins. The content of antinutrient factors in tubers of three *Dioscorea* spp ranged from 158.1 – 837.41 mg/100 g EP - tannin, 2.41 – 2.81 mg/100 g - oxalate, and 31.06 – 90.17  $\mu$ g/100 g - phytate. The results showed that these underutilised fruits and vegetables are good sources of protein, minerals and vitamins, capable of supplementing locally predominant starchy diets. Also, the minimum amount of antinutrient factors would be advantageous for their assimilation. Therefore, adequate management and promotion of their consumption may have an impact on the dietary quality of the rural and urban populations.

**Keywords:** Antinutritional factors, biodiversity, diet diversity, nutrition, wild food plants

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## Contribution of Indigenous Edible Insects to Food Security in Rural and Urban Zimbabwe

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The world's growing population and food securities challenges have necessitated the need for using sustainable natural resources. Consumption of insects is a traditional practice since time immemorial in most developing countries. However, the potential contribution of edible insects to food security in these countries is under threat. Adoption of western food habits, especially in urban areas, has caused a decline in the consumption of edible insects. The study aimed at assessing the potential contribution of edible insects to food security in urban and rural areas. For this purpose, a survey was conducted in three urban towns and five rural districts to determine the current consumption patterns and influencing factors for indigenous edible insects in general, and specifically also on *Eulepida* species and *Henicus whellani* species. The case study was conducted amongst 200 urban and 175 rural respondents. Furthermore, a nutritional analysis of the two insect species sampled from five rural districts was performed. Consumption and nutritional data were used to assess the potential contribution of the insects to food security. Results showed that a greater percentage of rural respondents (89.7%) consume at least one edible insect as compared to urban (80%) respondents. A less than 50% respondents in both the rural and urban areas consume *Eulepida* species and *Henicus whellani*. Frequency of consumption of edible insects in rural areas was significantly higher in rural than in urban areas. Rural respondents (63.9%) consumed insects more than three times a week as compared to 14.5% for urban consumers. With a high protein content of 55% and 68% on dry basis for *Eulepida* species and *Henicus whellani*, respectively, consumption of these insects can contribute to meeting the daily protein requirement. The iron (24.2 – 52.85 mg/100g) and zinc content (10 – 20.85 mg/100g) are high for both *Eulepida* species and *Henicus whellani*, making them also a potential mineral-containing ingredient for use in food enrichment. However, the low insect consumption level in urban areas due to restricted availability limits the actual contribution to food security. This justifies the need to improve edible insects availability, especially in urban areas through developing reliable value chains, insect farming and processing

**Keywords:** Consumption patterns, edible insects, food security, Zimbabwe

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## What Is Planted Is Not Eaten – Using Production Diversity to Link Agrobiodiversity and Dietary Diversity

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Agrobiodiversity and diversified production on smallholder farms influences household dietary diversity. However, empirical evidence to support this assumption is limited. Conventional biodiversity indicators (i.e. species richness (SR), Simpson diversity (SD)) use only species counts. They include neither information on the quantity and quality, nor other factors affecting production. Our objective is to develop an indicator, i.e. production diversity (PD), measuring the role of diversity in crop production for human nutrition. We hypothesise that PD (i) shows a clear relationship between agrobiodiversity and dietary diversity of farming households; and (ii) includes the impact of abiotic and biotic factors such as erratic rainfall and low soil fertility on productivity.

Data was collected from 72 farming households in Teso South, Kenya during the 2016 long rain season (LRS) and the 2016/17 short rain season (SRS), including total crop lists and their corresponding yields (kg). Qualitative 24h-recalls, were done with the primary caregiver in the household, and used to calculate the individual dietary diversity score (IDDS). SR (sum of all species) and SD (number and abundance of species) were calculated using the crop lists. PD was calculated by summing yields from the crop list into 10 food groups, and using the formula for SD, calculating diversity of food groups. All indicators were compared using polynomial regression models.

PD and SR were higher in the LRS (mean PD = 0.55, SD = 0.2; mean SR= 10, SD = 4.4), than in the SRS (mean PD= 0.38, SD = 0.25; mean SR= 8, SD = 3.3). In the LRS, PD and IDDS showed a significant positive correlation ( $R^2= 0.19$ ;  $p = 0.002$ ), but not in the SRS ( $R^2=0.09$ ;  $p = 0.052$ ). In contrast, no significant results or trends were found using SR or SD. Therefore, when total food production is high (LRS), household consumption of self-produced foods is also high, whereas when production is low (SRS), the use of self-produced food decreases. Only at times of high productivity does agrobiodiversity affect IDD. The results show, that production diversity is more capable of revealing the role of agrobiodiversity for dietary diversity, by including factors affecting crop productivity, than conventional biodiversity indicators.

**Keywords:** Agriculture, biodiversity, crop production, dietary diversity, Kenya, production diversity

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## **Participatory Approach to Increase Dietary Diversity through Agricultural Activities and Nutrition Education in Western Kenya**

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This research examines the suitability of a community-based participatory approach to increase dietary diversity through agricultural activities and nutrition education in Vihiga County, western Kenya. It arises from a project that is part of the nutrition cross-cutting cluster work within Humidtropics, a CGIAR research programme. The project consists of a baseline survey covering agricultural biodiversity and nutrition of women and small children, a phase of participatory development and implementation of community activities to improve nutrition and an endline survey. During the baseline survey, data was collected in 10 randomly selected sub-locations in Vihiga County. After pair-matching, five (intervention sub-locations) of the 10 sub-locations took part in participatory workshops to develop community activities to improve nutrition, while the other five served as control. During the first year of implementing the chosen activities, the communities received agricultural training and nutrition education. The endline survey covered the 10 sub-locations surveyed at the baseline. Within the five intervention sub-locations, households were further stratified as beneficiaries (participating in development and implementation of activities; receiving agricultural training and nutrition education) and non-beneficiaries (receiving nutrition education). Even though Vihiga County is rich in local food biodiversity (67 cultivated and 38 wild edible species), diets lack diversity. In the participatory workshops the communities decided to do kitchen gardening and poultry raising to diversify diets. Children and women from the control group had significantly lower mean dietary diversity scores (4.0 and 4.8, respectively), compared to the non-beneficiaries (4.5 and 5.3, respectively), and beneficiaries (4.6 and 5.5) ( $p = 0.000$ ). A much higher proportion of children and women of the control (28% and 30%, respectively) than in the non-beneficiary (10% and 15%, respectively) and beneficiary group (12% and 13%, respectively) did not meet minimum dietary diversity. Looking at dietary diversity and the measures applied to improve it, it can be assumed that nutrition education had the greatest effect, before participatory agricultural activities and agricultural trainings. This assumption however only derived from the endline data analysis. Baseline and endline survey data still need to be compared in order to verify which of the measures worked toward the improvement of dietary diversity.

**Keywords:** Agrobiodiversity, community-based participatory approach

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## Delivery of Nutrition Education through Agricultural Extension: Evidence from a Randomised Trial in Rural Kenya

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The relationship of nutrition and agriculture has long been established and agricultural technologies and extension can play an important role in stabilising food security. However, agricultural and nutritional programs are mostly implemented independently. Acceptance of nutrition education on specific topics and agricultural extension has shown positive effects by itself, but to our knowledge has not been tested in a merged setting. Therefore, the present study wants to test the effectiveness of nutrition education, when delivered through agricultural extension. A one-year intervention introduced nutrition education within an agricultural program, which introduced pro-nutrition innovations. Unit of intervention were existing common-interest groups (CIG's) in two counties in Kenya. In a multi-stage sampling strategy, 48 CIG's were randomly sampled. In the next stage 20 members of each group were interviewed. For the intervention a randomised control trial design was introduced and CIG's were randomly assigned into treatment (24) and control (24) groups. Treatments included agricultural training on two nutrition-sensitive technologies and a combination of nutrition education covering 'introduction of nutrients', 'nutrition during different life cycles and health'. At baseline in late 2015, 809 households were interviewed about their dietary behaviour. Anthropometric data was collected for two adults and a child between six to 59 month of age of each household, as well as nutrition knowledge. Follow-up data on the same household was collected in late 2016.

At baseline, dietary diversity of the households depict usage of nine food groups and energy intake was 3243 kcal per day and adult equivalent. At individual level energy and food group consumption was slightly lower. At baseline no significant differences between the two groups were found concerning dietary diversity, dietary quality and anthropometric measures, except at individual dietary diversity (IDD) and Body mass index (BMI) measures (IDD  $t(1024)=2.57$ ,  $p=0.0115$ ; BMI  $t(1042)=3.12$ ,  $p=0.000$ ). Next step is to analyse difference between our two data round to test the effectiveness of the nutrition education intervention. We test the effects of nutrition training on nutrition knowledge, indicators of dietary quality at different levels, as well as anthropometric measures.

**Keywords:** Agricultural extension, dietary diversity, Kenya, nutrition education, RCT

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## The Impact of Wild Plant Foods in Reducing the Minimum Cost of a Nutritious Diet in Turkana, Kenya Using Linear Programming Modelling

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The objective of this study was to determine the minimum cost of a nutritious diet for children: 6–8 months, 9–11 months, and 12–23 months and women (15–49 years): non-pregnant/ non-lactating, pregnant and lactating by modelling locally available foods with or without wild plant foods. Three pastoralists and three agro-pastoralists villages were randomly selected from a list. Market surveys were conducted in each village for plenty and lean seasons in 2016. Focus group discussions (FGD) were held with ten women per village to determine culturally accepted dietary habits (minimum and maximum constraints of food) and these constraints were verified against the 25<sup>th</sup> and 75<sup>th</sup> percentiles of actual dietary intake from a 24h recall tool applied to 180 households. Results from a FGD on agrobiodiversity following the 4- cell methodology developed by Bioversity International were used to select three wild vegetables and three wild fruits for modelling. All data were entered in the Cost of Diet software developed by “Save the Children UK” to model a Locally Adapted Cost Optimised Nutritious (LACON) diet.

The modeled LACON diet without wild plant foods costs between 49–101 Kenyan Shillings (KES) (\$0.5- \$1) daily in the plenty, and between 59–119 KES (\$0.6- \$1.2) in the lean season for children 6–8, 9–11 and 12–23 months. For non-pregnant/ non-lactating, pregnant and lactating women it costs between 173–247 KES (\$2- \$2.4) and 226–304 KES (\$2.2-\$3) respectively in the plenty and lean seasons. Diets modelled with all wild vegetables reduced to a large extent the cost of diet for all groups in both seasons. The most significant cost reduction was found by adding *Solanum americanum*, for pregnant women in both seasons, namely 47 % cost reduction. Iron and zinc nutrient deficiencies were found in LACON diets without wild plant foods of all groups except lactating women.

Models with all wild vegetables provided the cheapest LACON diets, but they still remain unaffordable for most households in Turkana irrespective of their wealth level. Nonetheless, wild plant foods have a positive impact on the reduction of the cost of diets as well as making up for nutrient deficiencies.

**Keywords:** Affordability, cost of diet, LACON, wild plant foods

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## Fermentation and Addition of Malt to Improve Physicochemical and Sensory Properties of Complementary Foods Prepared from Starchy Grains

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Inadequate complementary feeding, like constantly feeding young children with bulky starchy complementary foods (CFs) as it is practised in sub-Saharan African countries like Ethiopia, is an immediate cause of child malnutrition. Yet, there are several modification techniques that can improve chemical, physical and sensory properties of starchy foods. This study was conducted to evaluate the combined effects of fermentation duration and malt concentration on physicochemical and sensory properties of starchy cereals commonly used for making CFs in Southwest Ethiopia.

Three fermentation times (0, 24 and 48 hours), three malt concentrations (0, 2 and 5 %) and three cereal flour types (oats, barley and teff) were combined in a factorial arrangement. The samples were analysed for proximate, mineral and anti-nutritional factors compositions, physical and sensory properties. Treatments were compared using analysis of variance and Tukey's studentized range test, at 5 % level of significance.

The proximate composition and calorific value ranged between 3.67 – 6.17 %, 1.75 – 2.71 %, 8.12 – 16.82 %, 1.63 – 4.55 %, 1.58 – 5.96 %, 71.20 – 78.18 % and 359.33 – 380.26 kcal for moisture, ash, protein, fat, fiber, carbohydrate and energy, respectively. The calcium, iron and zinc contents ranged between 46.9–143.85 mg/100g, 2.97 – 31.39 mg/100g, 1.59 – 2.86 mg/100g, respectively. The anti-nutritional factors ranged between 18.63 – 175.07 mg/100g for phytate and 0.84 – 42.89 mg/100g for tannin. The viscosity, water absorption capacity and bulk density values ranged between 235.00 – 1016.33 cP, 61.33 – 143.12 % and 0.66 – 0.99 g ml<sup>-1</sup>, respectively. Interaction of fermentation duration and malt concentration resulted in a significant ( $p < 0.01$ ) reduction in crude fiber, crude fat, total carbohydrate, phytate, tannin, bulk density and viscosity in all the three cereals. In the contrary, crude protein and calorific value were significantly ( $p < 0.01$ ) increased by the interaction effect. Ash and mineral contents were not affected. Gruel samples prepared from 48 hours fermented cereal flours were ranked lowest by the sensory panelists. Whereas, gruels made from 24 hour fermented and unfermented cereals were ranked favourably for appearance, aroma, taste, mouth feel and overall acceptability.

Addition of 5 % malt and fermentation for 24 hours appear to have a promising synergistic effect in improving chemical, physical and sensory qualities of fermented starchy staples commonly used making CFs. Further research on storability of these products is recommended.

**Keywords:** Amylase, complementary foods, fermentation, starch, upgrading

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## Diversity and Nutritional Characteristics of *Garcinia kola* Heckel (Clusiaceae) in Southwest Cameroon

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*Garcinia kola* (Clusiaceae) is a fruit tree species indigenous to West and Central Africa. The tree is frequently called ‘wonder plant’ because all its parts have medicinal properties. In Cameroon, seeds of *G. kola* are widely used by locals for treatment of gastric problems. Studies on *G. kola* have mostly focused on its bioactive substances. However, information on intraspecific diversity and the exact nutritional values of the seeds remain unclear. Therefore, the objective of this study was to assess and describe morphological diversity and nutritional status among different populations of *G. kola* from the Southwest region of Cameroon. For examination of the species’ current management and utilisation practices, we visited 50 farms and interviewed 48 farmers. Further, morphological characteristics of 759 fruits, 1,821 seeds and 402 leaves coming from 81 individual trees were examined and botanical descriptors were developed based on the species morpho-types. Seeds of each tree were subjected to nutritional analyses for: ash, moisture, crude fat, fibre, protein and NFE (nitrogen-free extract) content. The nutritional values were determined as follows: ash 0.33 %, moisture: 11.4 %, crude fat: 1.48 %, crude fibre: 2.27 %, crude protein: 6.48 % and NFE: 78.02 %. We did not find any significant differences between our study sites; however, results suggest that morphological diversity within a single population is much higher than the diversity among populations from different sample sites. The process of *G. kola* domestication seems to be at its very beginning, although we identified some efforts in terms of species-targeted cultivation and selection. It is expected that this study may provide the basics for the first steps of *G. kola* domestication. In future, research on the species population genetics as well as its secondary metabolites content should be conducted to complement our data and further promote the domestication process.

**Keywords:** Bitter kola, Central Africa, domestication, indigenous fruit trees, phytochemistry

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## Nutrient Composition of Guava (*Psidium guajava* L.) Fruits as Influenced by Soil Nutrients

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Guava is appreciated both as a fresh fruit and an industrially processed product in the form of juices, jellies, and sweets. It's rich in sugars, minerals and vitamin C. The demand for guava and guava products is rising due to the increasing health consciousness and the fruit's much appreciated nutritional benefits. There is, however, limited knowledge of the effect of soil properties in terms of nutrients on guava fruit quality. A study was conducted on the nutritional composition of fruits from 128 trees in four regions of Kenya (Riftvalley, Coast, Western and Eastern). Out of these, 50 trees were selected for additional soil sampling under their crown. The edible portion of the cleaned fruits (pulp plus skin) was divided into two sub-samples. One fresh sub-sample was used to analyse Vitamin C, total acidity, and brix immediately after preparation. The other sub-samples were freeze-dried and later used to analyse proteins, sugars and minerals (Ca, Mg, K, Na, P, and Zn). The soil samples were air-dried and sieved through a 2 mm mesh. Later, minerals were determined by the CAT method. Soil nutrient contents were correlated with fruit nutritional composition of the respective 50 samples by applying Pearson correlation method. Fruit vitamin C content, which was highest in the Eastern region (195.8 mg/100g edible portion) was positively associated with soil Cu content ( $r=0.465$ ;  $p = 0.01$ ) that had also a weak positive correlation with fruit protein content ( $r=0.297$ ,  $p = 0.05$ ). Soil N values, which were lowest in Coast (0.07 %), were negatively correlated ( $r=-0.463$ ,  $p = 0.01$ ) with Brix values, which were highest (12.9 %) in fruits from the Coast. Soil K content was positively associated with Ca content in the fruits, which was highest in Riftvalley region (112 mg/100g edible portion). Results of our study could help developing a fertiliser regime for guava trees that would improve not only yield, but also quality and nutritional composition of the fruits. The surprising role of soil Cu in enhancing the Vitamin C content of guava fruits needs to be studied in more detail.

**Keywords:** Guava fruit, nutritional composition, quality aspects, soil Cu, vitamin C, yield

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## Dietary Diversity, and Nutritional Status of Mother-Child Pairs by Season in *Enset* Cultivating Areas of Southern Ethiopia

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Several cross-sectional studies indicated a food insecurity problem in South Ethiopia. However, seasonal trends of diet and nutritional status of mother-child pairs weren't well studied in *enset* cultivating areas of the region. Therefore, this community-based longitudinal study was designed to assess diet diversity, and nutritional status of mother-child pairs by season. The study was conducted on 625 randomly recruited mother-child pairs from Shebedino and Hula woredas of Sidama zone in southern Ethiopia. Data collection was conducted twice, first from January to early February 2017 (dry season), and second round in June 2017 (wet season). Two days 24-hrs mother-child pairs' dietary recall data was collected. Anthropometric measurements were taken following standard procedures. Of the total, 578 mother-child pairs completed the study, making the response rate 92.5%. Dietary data was analyzed for 145 mother-child pairs randomly selected from the total. Male children accounted for 50.3% with mean age of 38.3 (8.50) months in both sexes. More than 95% of the study participated mother-child pairs were from Sidama ethnicity. Religiously, 91.5% of the study participated mothers were protestant with the rest being Muslim (5.9%), orthodox (1.4%), and Catholic (1.2%) religion followers. More than half of the mothers were from male headed households with 97.6% co-habiting at the time of the survey. Mean family size was 5.2 (1.78). Educational achievement of the mothers involved in this study was low, 24.2% attended grade 1-4 with 41.3% being illiterate. Majority of the mothers (87.7%) were housewives. A paired-samples t-test proved statistically significant negative mean change for wasting, underweight and stunting among study participated children aged 24-59 months. This study demonstrated that more number of children become wasted and underweight in wet season before green maize harvest in *enset* cultivating areas of southern Ethiopia.

**Keywords:** *Enset* cultivating areas, dietary diversity, mother-child pairs, nutritional status, season

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## Stinging Nettle (*Urtica simensis*): An Indigenous But Unrecognised Micronutrient Potential for Combatting Hidden Hunger in Ethiopia

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The aim of this study was to investigate the micronutrient potential of stinging nettle (*Urtica simensis*) grown in Ethiopia. For this experimental study, samples were collected from Chacha, North Shewa zone of Amhara Regional State in June, 2016. Samples were divided into three groups. Lyophilized group was directly stored at  $-80^{\circ}\text{C}$  whereas the other two groups underwent shade (at  $20\text{--}22^{\circ}\text{C}$  for 9 days) or sun (for 11 hours and 20 minutes) drying processes. Vitamins such as carotenoids (lutein, zeaxanthin,  $\beta$ -cryptoxanthin, 9-cis- $\beta$ -carotene, 13-cis-  $\beta$ -carotene,  $\alpha$ -carotene and  $\beta$ -carotene), thiamine, vitamin C and  $\alpha$ -tocopherol were analysed using HPLC at Institute of Biological Chemistry and Nutrition whereas, minerals such as Ca, K, Mg, P, Fe, Mn, Zn, Cu, Co, I and Se were measured at Landesanstalt für Landwirtschaftliche Chemie, University of Hohenheim, Stuttgart, Germany. The total moisture content of the samples was about 84%. Based on the lyophilized samples, the concentrations of thiamine, vitamin C and  $\alpha$ -tocopherol were  $62.19 + 3.04 \mu\text{g}/100 \text{ g}$ ,  $105.63 + 5.27 \mu\text{g}/100 \text{ g}$  and  $1.53 + 0.03 \text{ mg}/100 \text{ g}$ , respectively. The concentrations of carotenoids were  $11.96 + 0.257 \text{ mg}/100 \text{ g}$  lutein,  $0.52 + 0.016 \text{ mg}/100 \text{ g}$  9-cis- $\beta$ -carotene,  $0.30 + 0.13 \text{ mg}/100 \text{ g}$  13-cis-  $\beta$ -carotene,  $0.32 + 0.009 \text{ mg}/100 \text{ g}$   $\alpha$ -carotene and  $7.92 + 0.15 \text{ mg}/100 \text{ g}$   $\beta$ -carotene. They have high content of Ca ( $813.04 + 2.29 \text{ mg}/100 \text{ g}$ ), K ( $899.90 + 4.06 \text{ mg}/100 \text{ g}$ ), Fe ( $21.25 + 0.76 \text{ mg}/100 \text{ g}$ ) and Zn ( $1.28 + 0.04 \mu\text{g}/100 \text{ g}$ ). Comparing the three drying processes, lyophilized group contained the highest concentrations of lutein,  $\beta$ -carotene and minerals. In conclusion, *Urtica simensis* is a rich indigenous micronutrient resources to curb the issue of hidden hunger in Ethiopia.

**Keywords:** Ethiopia, hidden hunger, micronutrients, stinging nettle

## Food Security, Dietary Practices and Nutrition Status of Mothers/Caregivers and Children in Laikipia County, Kenya

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Food availability and access in the household determines the dietary practices and nutrition status of mothers and children. This study was conducted in Laikipia County; an arid and semi-arid region in Kenya, experiencing food insecurity and undernutrition. The study assessed household food security status and determined its relationship with dietary practices and nutrition status of mothers and children. Four villages were selected from vulnerable areas in the County, 152 children aged 6–59 months and their mothers/caregivers were randomly sampled. A structured questionnaire was used to collect data on household food production and purchase, dietary diversity of mothers and children, and anthropometric measurements. The mean land size was 0.7 hectares and 55 %, 41 % and 33 % of the households grew staples/pulses, vegetables and fruits on-farm respectively, mostly for home consumption while 81 % kept livestock. The mean weekly expenditure on food was KES 820±660 (mostly on starchy staples). The total amount of money spent weekly on food was significantly correlated with the mother's BMI ( $r_s=0.166$ ) but not with the children nutrition status. Twenty eight percent of the children were stunted, 16 % underweight and 2 % wasted, while 16 % of the mothers were underweight, 52 % normal and 32 % overweight/obese. Sixty four percent of the caregivers did not achieve the minimum dietary diversity score of five food groups a day. Most commonly consumed food groups by caregivers were cereals (100 %), milk/milk products (79.6 %), dark green leafy vegetables (63.2 %) and other vegetables (67.8 %), only 30 % consumed a fruit. Cereals, oils/fats and milk/milk products were consumed by most children ( $\geq 80$  %) but animal source foods such as eggs, meat and fish were consumed by  $<7$  % of the children. The proportion of children who consumed vegetables was significantly higher (70 %) in households that cultivated vegetables than (48 %) those that did not ( $p = 0.008$ ), while underweight was significantly ( $p = 0.019$ ) higher among children from households that did not grow fruits. In conclusion, the dietary practices and nutrition status of mothers and children in Laikipia County are suboptimal and are influenced by household food access (purchases) and availability (production on-farm). Increased fruit and vegetable cultivation could enhance household food security, dietary practices and nutrition status.

**Keywords:** Food access, food groups, food production, minimum dietary diversity

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## Rural Agriculture for Improved Nutrition: Stakeholder Insights from Different Sectors in Tanzania

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Nutrition sensitive pathways and approaches involving agriculture are being recognised as essential to guarantee nutrition security and lessen undernutrition. In Tanzania, the majority of the population lives in the rural areas and 80 % depend on agriculture as the main source of livelihood. Although agriculture can play a big role in alleviating undernutrition, its role in tackling malnutrition needs to be dealt with based on policies to the actual implementation.

This study aimed to investigate perspectives of stakeholders on links between rural agriculture and nutrition, opportunities and challenges, evidences and policy inferences.

**Methodology:** Open ended interviews were conducted with 11 stakeholders identified for the Scale-N project in Tanzania who contribute in one way or another to the nutrition sector. Two focus group discussions with 20 farmers from Mzula and Tindiga villages in Dodoma and Kilosa were conducted.

Stakeholders acknowledged obstacles to better achievement of undernutrition reduction which included absence of clear cut motivations in the agriculture sector regarding enhancing nutrition, concentrating on cash crops, lack of accountability for agriculture matters for improving nutrition, policies exist but putting them into action is hindered, limited competence in the available human resources, absence of coordination between sectors, lack of proof that agriculture works for nutrition and economic constraints to support agriculture. Possible measures mentioned to be taken to improve rural agriculture for better nutrition including home gardening with different crops, nutrition training, better access to markets and labour saving technologies to women. From the farmers' side, 13 mentioned lack of extension services, 17 mentioned lack of access to agricultural productive resources, lack of knowledge about nutritious and safe food and the majority mentioned increased occurrences of natural disasters such as floods and serious drought.

Numerous possibilities are present to strengthen the role of agriculture on nutrition in Tanzania, however, there is need to strengthen the structure and making of policies which will in turn need proper implementation for the desired success.

**Keywords:** Agriculture, nutrition, policy, rural

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## An Assessment of Household Dietary Diversity and Vegetable Consumption: Case Study of Smallholder Farmers in Yayu Biosphere Reserve, Ethiopia

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The household dietary diversity score (HDDS) has been increasingly used as indicator for economic ability of a household to access a variety of foods. For this paper 308 rural households in Yayu biosphere reserve, Ilu Ababora Zone, Oromia National Regional State, Ethiopia were interviewed. The data was collected in April/May 2016 prior to the implementation of NutriHAF Africa Project. The latter aims to integrate appropriate vegetables into multi-storey cropping systems to increase nutrition security, diversify and intensify agriculture and thus to reduce pressure on natural habitats in biodiversity hotspots. Following the FAO (2010) guideline for measuring household dietary diversity, respondents were asked to recall all foods eaten and beverages taken by the whole household on the previous day.

The results show a mean HDDS of 5.2 (SD=1.9). In addition, it was analyzed which food groups were predominately consumed at different levels of the scores and whether dietary diversity is correlated to the household economic status and meal frequency. While 60 % of households had a medium HDDS of 4–6 food groups (N=186) about equal shares of households had either a low HDDS of  $\leq 3$  (N=58) or a high HDDS of 7–12 (N=64). The food groups mainly consumed by households with low HDDS were cereals, white tubers and roots, and legumes/nuts/seeds while only few consumed vegetables (5.2 %) or fruits (3.4 %). In contrast, most households with high HDDS consumed vegetables (95.3%) and fruits (85.9 %) while those with medium HDDS only to some extent (vegetables 58.1 %; fruits 17.2 %). Dark green leafy vegetables were consumed by only 7.5 % of all households. The respondents were also classified as poor, middle and high income based on their economic status. As expected, economically better off households were identified with higher meal frequency and higher HDDS while poorer households with low HDDS were identified to have fewer meal frequency.

In order to assess the change in the HDD situation and vegetable consumption one year after the intervention of the NutriHAF Africa project, including the introduction of new vegetable species, a second round survey in April 2017 took place and data will be included in the final analysis.

**Keywords:** Ethiopia, household dietary diversity, leafy vegetables, meal frequency



## Diet Adequacy of Male Ugandan Farmers – A Cross-Sectional Case Study in Kapchorwa District of Uganda

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**Background:** Eastern Uganda is the second most food insecure region and has the poorest dietary diversity of the country. Data on men's diet adequacy are scarce. The objective of this study was to assess the diet composition, dietary diversity and energy balance as well as the nutritional status of male farmers in Kapchorwa District, Mid-Eastern Uganda.

**Methods:** An agriculture-nutrition baseline study was conducted in May-June 2016 (baseline, t0) and August-September 2016 (follow-up, t1) within the research project "Linking agriculture and nutrition for a healthy diet "HealthyLAND" in Kapchorwa District, Uganda. Structured in-terviews were conducted among randomly selected farm households with children below five years in Kapchorwa District. This study included 187 men (t0) and 79 men (t1), respectively. Intakes of energy and macronutrient intake as well as the Individual Dietary Diversity Score (IDDS) were calculated based on a semi-quantitative 24h-dietary-recall. Anthropometric measurements for calculating body mass index (BMI) and 24-hour physical activity recalls were included to estimate total energy expenditure and energy balance.

**Results:** At baseline, the mean farmers' BMI was 21.2 (SD=3.26), with 15 % classified as underweight, 75 % of normal weight, 8.7 % as overweight and 1.6 % as obese. The mean energy intake was 2426 kcal day<sup>-1</sup> (SD=853). The mean energy balance was negative, -583 kcal (SD=1093), with 72 % farmers having a higher energy expenditure than energy intake. The IDDS (mean (SD)) did not differ significantly between the two seasons during pre-harvest season during harvest season, (4.4 (1.2) and 4.5 (1.3),  $p = 0.397$ ). Differences between seasons were found in the consumption of pulses (49 vs 67 %,  $p = 0.054$ ) and "other fruits" (33 vs. 20 %,  $p = 0.021$ ). The Anova showed that IDDS is significantly positively associated with school education level and energy intake ( $p < 0.01$ ).

**Conclusion:** The findings confirm a poorly diversified diet that lacks an adequate energy and nutrient supply. This limits the farmers' capacity to intensify their farming activities needed to improve nutrition security.

The authors acknowledge the contribution of Jan Welsch during study design and thank the DAAD as well as BLE and BMEL for the financial support of this study as part of the Healthy-LAND project.

**Keywords:** Agrobiodiversity, dietary diversity, energy balance, Kenya, men

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## Dietary Diversity and Micronutrient Status of School Children in Chamwino and Kilosa Districts, Tanzania

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Childhood is a period of rapid growth, during this stage of life micronutrient deficiencies can lead to retarded growth, anaemia and reduced immune function. Poor feeding practices and limited dietary diversity are contributing factors to poor micronutrient status. Deficiencies of vitamin A, zinc and iron co-exist in malnourished children.

The Scale-N study aims to improve nutritional and micronutrients status (vitamin A, iron, zinc) in school-children (5–10 years) in 2 villages in Chamwino and 2 villages in Kilosa districts, Tanzania (scale-N.org). During baseline study, 666 children were randomly recruited to obtain information on demographic characteristics, anthropometry, Household Dietary Diversity Score (HDDS), and to collect blood for the determination of haemoglobin (hemocue method) and micronutrient status (serum vitamin A, iron and zinc by enzyme-linked immunosorbent assay and spectrophotometric methods). Data are presented as means (SD) and prevalences and compared using ANOVA, and chi-squared test.

The prevalence range of underweight and stunting were 11–17 % and 25–35 % with no significant differences between villages/districts. Anaemia, iron-, vitamin A deficiency and low serum zinc among children in the study villages showed a prevalence range of 19–69 %, 15–40 %, 8–19 %, and 20–49 % respectively. Children from villages of Kilosa had significantly higher prevalence of anaemia (59 and 68 % vs. 19 and 26 %) and iron deficiency (37 and 40 % vs. 19 and 15 %) than those of Dodoma. The overall mean HDDS was  $4.8 \pm 1.8$ . The households of Kilosa villages had higher HDDS than those in Dodoma (5.7 and 6.2 vs. 4.2 and 3.0,  $p < 0.001$ ). The higher HDDS in Kilosa district contributed mainly by reported consumption of foods such as sugar, fats/oil and beverages. The least consumed food groups in both districts were meat/organ, eggs and milk products.

The higher diversity score consisting of food groups such as sugar, oil and beverages was associated with higher prevalence of anaemia and iron deficiencies. Pro vitamin A rich vegetables/fruits and animal based foods are highly recommended 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 diversity, iron, school children, vitamin A, zinc

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## Mainstreaming Biofortification in Africa: A Contribution Towards Reducing Malnutrition and Hunger

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Adequate progress has been made towards reduction of the menace of micronutrient deficiency through cassava biofortification across Africa. In Nigeria, 6 biofortified cassava varieties have been officially released by IITA and partner NRCRI with total carotenoids content ranging from 6.1 to 10.4  $\mu\text{g g}^{-1}$  of fresh weight. These varieties will reach about 2 million farmers by 2018. On-going research effort by IITA and partners is geared at reaching the 3<sup>rd</sup> wave target of 15  $\mu\text{g g}^{-1}$  of fresh weight has already identified promising pipelines genotypes with sufficient potentials.

This success story has been achieved through concerted effort in breeding and dissemination strategies using diverse platforms. Breeding strategies incorporates cultivar development with building the capacity of NARS across Africa for sustained qualitative research that promotes sustained impact of the gains from biofortification into the future. These interventions are achieved through training on fast screening method of total carotenoids quantification using the iCheck<sup>TM</sup> device, training on the use of tablets to enhance qualitative data collection and data capture, enhanced knowledge on data sharing and repository through training on cassava base and also the use of various dissemination and awareness creating platforms towards sensitization and increased awareness through farmers field days, Nutritious food fairs, commercialised Agroshop online market and model villages across several communities.

A paradigm shift towards the approach to awareness creation combines nutrition campaigns with training on new nutritious food forms and value addition as well as understanding gender preference for biofortified cassava varieties.

The outstanding results from combining these various strategies have yielded substantial positive results towards increasing the acceptability of biofortified cassava varieties and products in Nigeria and across Africa. Hence the development of a vibrant and stronger cassava value chain with multi-sectoral engagements and new markets now is developing in Nigeria. These promotes access to biofortified products, increase the cash returns to farmers and promotes industrial growth thereby reducing hunger and malnutrition and ensuring food security and increased income for farmers in SSA.

**Keywords:** Awareness, biofortification, cassava, genotypes, malnutrition

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## Factors Influencing the Nutritional Status of Women of Reproductive Age in Teso South Sub-County, Kenya

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**Introduction:** In spite of the agricultural potential in rural areas, food insecurity and poor quality diets remain a challenge. These contribute to malnutrition, both under and overnutrition among women of reproductive age (18–49 years). This study aimed to investigate the factors influencing nutritional status of women of reproductive age in a rural setting in Western Kenya  
**Method:** A cross sectional nutrition survey was conducted in May-June 2016 (pre-harvest season) targeting a random sample of 418 farm households with women and their children aged 6–59 months in Teso South Sub-County. Semi-structured questionnaires were used to collect socio-demographic and agricultural practices data. The 24-hour dietary recalls were used to assess the women's dietary intakes. The Minimum Dietary Diversity – Women (MDD-W) was calculated as indicator for dietary diversity. Food insecurity was measured using the Household Food Insecurity Experience Scale. The weight and height measurements were assessed to compute body mass index (BMI) of the women.

**Results:** Among the surveyed households, the prevalence of moderate and severe food insecurity was 23.4 % and 46.4 %, respectively. Mean (SD) women's dietary diversity score was 4.2 (1.24) out of 10 food groups. The most consumed food group was cereals (87.3 %) followed by other vegetables (80.1 %) and dark-green vegetables (65.0 %) while the least consumed were nuts and seeds (4.8 %). The proportion of women who achieved MDD-W was 43.6 %. The prevalence of underweight and overweight/ obese was 10 % and 22.2 % respectively. Bivariate correlation analysis indicated that wealth index ( $r=0.79$ ,  $p = 0.117$ ), kitchen gardening ( $r=-0.027$ ,  $p = 0.600$ ), food insecurity ( $r= -0.063$ ,  $p = 0.218$ ) and dietary diversity ( $r= -0.022$ ,  $p = 0.685$ ) had no significant correlation with BMI of the women.

**Conclusion:** These results indicate that wealth index, kitchen gardening, food insecurity and dietary diversity do not have a significant influence on the nutrition status of women in Teso. This implies there may be other significant factors. There is need for further studies considering other variables which may show significant influence on the nutrition status of women in rural settings of Kenya.

**Acknowledgement:** This work was conducted with the financial support of the German Federal Ministry of Food and Agriculture, through the HealthyLAND project.

**Keywords:** Dietary diversity, food security, nutritional status, rural, women

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## Supermarket Shopping and Nutritional Outcomes: A Panel Data Analysis for Urban Kenya

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**Background and objectives:** Overweight and obesity are growing health problems in many developing countries. Rising obesity rates are the result of changes in people's diets and lifestyles. Income growth and urbanisation are factors that contribute to these changes. Modernizing food retail environments may also play a certain role. For instance, the rapid spread of supermarkets in many developing countries could affect consumer food choices and thus nutritional outcomes. However, concrete evidence about the effects of supermarkets on consumer diets and nutrition is thin. A few existing studies have analysed related linkages with cross-sectional survey data. To our knowledge, we are the first to use panel data in this setting.

**Methods:** Panel data from households and a total of 1,199 adult individuals was collected in urban Kenya in the years 2012 and 2015. Panel regression models with individual fixed effects plus other controlling factors were employed.

**Results:** Our results show that shopping in supermarkets significantly increases adults' body mass index (BMI). Regarding impact pathways we did not find that supermarkets contribute to net increases in total calorie consumption. However, our panel data models revealed significant shifts in dietary composition. Supermarket shopping contributes to a sizeable decrease in energy consumption from unprocessed staples and from fresh fruits and vegetables. We found significant increases of supermarket shopping on energy consumption from dairy, vegetable oil, processed meat products (sausages etc.), and highly processed foods (bread, pasta, snacks, soft drinks etc.). These shifts towards processed and highly processed foods lead to less healthy diets, with higher sugar, fat, and salt contents, and probably lower amounts of micronutrients and dietary fibers.

**Conclusion:** The observed changes in dietary composition could explain the increasing effect on BMI, even without a rise in total calorie consumption. These results confirm that the retail environment affects people's food choices and nutrition. However, the effects depend on the types of foods offered. Rather than thwarting modernisation in the retail sector, policies that incentivize the sale of more healthy foods – such as fruits and vegetables – in supermarkets may be more promising to promote desirable nutritional outcomes.

**Keywords:** Dietary choices, Kenya, obesity, overweight, panel data, supermarkets

## Community Perceptions, Practices and Knowledge of Insects for Food in Kenya: A Case of Saturniidae

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Edible insects form a natural and renewable source of food with about 1,900 insect species being eaten worldwide by over 2 billion people. Over 60 % of edible insects in Africa belong to the order Lepidoptera, including saturniids. Despite consumption of saturniids in Kenya, documented information on the extent of consumption, perception and knowledge among communities in Kenya are lacking which is the focus of this study. It was carried out in 14 counties in Kenya, namely: Homabay, Siaya, Kakamega, Vihiga, Trans-Nzoia, Kilifi, Kwale, Machakos, Kitui, Nyeri, Meru, Taita, Makueni, and Laikipia. Semi-structured questionnaires were used to collect information from communities on knowledge, availability, consumption and potential for rearing of saturniids for sale and local consumption. Based on the feedbacks, we recorded the availability of seven saturniid species including *Gonimbrasia zambesina*, *Nau-darelia krucki*, *Bunaea alcinoe*, *Holocrina angulata*, *Imbrasia belina*, *Cirina forda* and *Epiphora bauhiniiae*. Among the respondents, more than 80 % indicated that they have collected insects for food. Termites, grasshoppers, crickets, compost grubs, saturniids and lake flies were collected by 88, 28, 7, 3, 8 and 2 % of the respondents, respectively. The Giriama people in Kilifi, coastal Kenya, were found to consume *G. zambesina* and *N. krucki*. In Kakamega, western Kenya, respondents >75 years of age indicated that they used to consume saturniids, while younger respondents refused to consume saturniids. However, more than 70 % of the respondents expressed interested in mass rearing of saturniids for business to regions where they are already consumed. Some respondents were ready to taste saturniids if processed and packaged. Lack of rearing protocols, ready markets and community acceptance were perceived as challenges by 85, 71 and 10 % of respondents, respectively. The main motivation for respondents to rear saturniids was to generate income. Enhanced awareness on the nutritional benefits of consuming saturniids, feasibility of mass rearing and opportunities for trade will be critical to mainstream saturniids among the edible insects in Kenya.

**Keywords:** Edible insects, mass rearing, saturniids

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## Edible Insects Used by the Amerindians Shipibo and Ashaninca of Ucayali High Basin in Peruvian Amazon

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Different insects such as beetles and ants, contribute to the protein and micronutrient intake of numerous human populations around the world. In the Peruvian Amazon, the insects represent a relevant food resource used as an alternative or complementary source of protein by indigenous communities. The study was conducted in 8 communities of 2 ethnic groups (4 Shipibo, 4 Ashaninca) of the upper Ucayali river basin. The main objective was to document the traditional knowledge on insect use, and to characterize collection and consumption patterns of edible insects among the communities. Samples of insects used as food were collected and preserved in vials with 70 % alcohol. Published taxonomical keys were used for the identification and characterization of the local insects. The data were collected based on thorough, semi-structured interviews with 61 (Shipibo) and 64 (Ashaninca) informants. In total, 5 insect species belonging to 3 families were considered edible for the Shipibos and Ashanincas. From taxonomical lens, they belong to Formicidae: *Atta cephalotes* (Squisapa); Curculionidae: *Rhynchophorus palmarum* (Suri), *Metamasius hemipterus* (Suri pequeño); Scarabaeidae: *Strategus jugurtha* B. (Papaso) and *Dynastes hercules* (Moho). The edible insects are collected and consumed by the communities according to their seasonal availability. Depending on the species, only certain developmental stages are consumed. The preparation of insects for consumption involves mainly roasting, boiling or baking with leaves.

**Keywords:** Alternative food sources, developmental stages, entomophagy, indigenous food system, seasonal availability, traditional knowledge

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# Economics

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1) Markets	433
2) Value chains	451
3) Risk and awareness	475
4) Institutions and livelihood	499

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# Markets

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## Oral Presentations

- ANDREA ESTRELLA:  
**Coffee Certifications: A Profitable Strategy for Improving the Livelihoods of Smallholder Farmers? Evidence from an Impact Evaluation in Colombia's Coffee Belt** 435
- LEONE FERRARI, INGRID FROMM, KATHARINA JENNY, ALEXANDRE MUHIRE, URS SCHEIDEGGER:  
**Formal and Informal Potato Seed Supply Systems Analyses in Rwanda** 436
- NKOYO BASSEY, ARNIM KUHN, HUGO STORM:  
**Marketers Consciousness for Quality Loss Reduction: A Case from Maize Marketers in Ghana** 437
- CATHERINE MWEMA, WIBKE CREWETT, JOB LAGAT, WOLFGANG BOKELMANN:  
**Filling Institutional Voids: Role of Social Networks in Horticultural Market Access, Evidence from Kenyan Smallholders** 438
- STEFANIA SELLITTI, MARTHA DEL RIO, CAROLINA GONZALEZ, PEDRO VICENTE, DIANA MARCELA CORDOBA:  
**Does Fair Trade Certification Improve Farmworkers' Welfare and Empowerment? Evidence from Nicaragua and Brazil** 439

## Posters

- HARRIET KYOMUGISHA, ERNST-AUGUST NUPPENAU, JOHNNY MUGISHA:  
**Determinants of Smallholder Farmer Market Choices: A Case of Organic Pineapple Markets in Uganda** 440
- NAGHMEH MOBARGHAEI DINAN, MANSOURE MAHLOUJI, HOUMAN LIAGHATI, REIHANEH RASOOLZADEH:  
**Comparison of Ecosystem Services Value of Conventional and Organic Farms in Fariman City, Iran** 441
- GETAW TADESSE GEBREYOHANES, CLEMENS LUTZ:  
**The Challenges of Producer Organisations in Impacting Smallholders' Productivity and Commercialisation: Evidence from Ethiopia** 442

HAMID EL BILALI, MICHAEL HAUSER, MARIA WURZINGER, LORENZ PROBST: <b>Alternative Food Systems: Using Space, Time, Integration and Rules as Narratives for Sustainability Transitions</b>	443
ERIC BETT, DAVID MICHAEL AYIEKO, EUSTACE KIARII: <b>Sustainable Agriculture Models and Willingness to Pay: A Matching Approach among Consumers in Kenya</b>	444
DIVYA RAJANNA, BENARD OTIENO ABEL, SHRIPAD BHAT, WOLFGANG BOKELMANN: <b>Implications for Linking of Smallholder Farmers to Markets: Role of Social Capital</b>	445
KATHRIN MEINHOLD, MUNTHALI CHIMULEKE, DIETRICH DARR: <b>Assessment of the Baobab Processing and Exporting Industry in Southern Africa</b>	446
ONDREJ PRIBYL, VLADIMIR VERNER, ANN DEGRANDE, DIVINE FOUNDJEM-TITA, ANNA MANOUROVA, PATRICK VAN DAMME: <b>Market Survey of <i>Garcinia kola</i> (Bitter Kola) Seeds in Yaoundé City, Cameroon</b>	447
LUIS LOSILLA, VERENA OTTER, ALEJANDRA ENGLER PALMA: <b>Internationalisation Paths of Chilean Fruit Export Companies: Are They Regionally or Globally Oriented?</b>	448
SANTI SANGLESTSAWAI: <b>Are Thai Consumers' Willing to Pay More for Local Fair Trade Rice</b>	449
MARTIN PAUL JR TUBE-OJONG, KAI MAUSCH: <b>Impacts of Improved Chickpea Adoption on Smallholder Commercialisation in Ethiopia</b>	450

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## Coffee Certifications: A Profitable Strategy for Improving the Livelihoods of Smallholder Farmers? Evidence from an Impact Evaluation in Colombia's Coffee Belt

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For the past decades, Voluntary Sustainability Standards (VSS) have been at the forefront of global sustainability governance in the coffee sector, in an effort to ensure transparency for the public and improve the livelihoods of smallholder coffee farmers. Raising farmer's income and ensuring economic sustainability should be considered a key measure of output legitimacy of certifications, as it has been the main incentive for producers to participate in these schemes. However, as certified products have entered the mainstream market, supply has vastly outpaced demand, thus turning coffee certifications into an entry barrier to certain markets and causing the price premium to erode. In addition, external circumstances beyond certifications such as the price volatility that characterises the sector, the uneven distribution of value and risks among the coffee value chain, the rise in input and labour costs, as well as the impacts of climate change, pests and diseases, are already pushing coffee farmers beyond the limits of profitability. For all those reasons, the capacity of VSS to ensure economic sustainability at the farm level has been put into question. So far, evidence from qualitative studies and the few rigorous evaluations conducted points to mixed and ambivalent effects of coffee certifications on farmers' livelihoods. What is more, most of these studies focus only on income from coffee, fail to accurately account for the costs of production and use small and non-representative samples. In this paper, we take broader impacts into account, assessing the effects at the plot, farm and household level, and account for substitution effects due to coffee specialisation. Using a matched sample of over 600 smallholder farmers from three cooperatives in Colombia's coffee belt to create a robust counterfactual, we first calculate the costs of production of both certified and non-certified farmers and then evaluate the impacts of third-party labels such as Fair Trade, Rainforest Alliance, and 4C, and company-led standards as Nespresso AAA and Starbucks C.A.F.E. Practices, as well as multi-certification strategies. The results of the study will shed light on the question of the effectiveness of VSS in terms of creating real change on the ground.

**Keywords:** Coffee certifications, economic impact, impact evaluation

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## Formal and Informal Potato Seed Supply Systems Analyses in Rwanda

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The potatoes production in Rwanda is constantly increasing and it represents an important food and cash source for farmers. The potato crop, together with maize, wheat, rice, beans and cassava is one of the six priority crops on which the CIP (Crop intensification Program) is focusing since 2007. Its production is mainly located at high altitudes in the Northern and Western provinces. The Nyabihu, Musanze, Rubavu and Burera districts, due to their favourable climatic conditions, are the 4 most productive districts accounting for about 60 % of the national potato production. However, because of the low quality seed use by farmers together with the low health soil status, yields remain low with an average of 11.6 t ha<sup>-1</sup>.

The aim of the study was to clarify the current formal and informal potato seed supply system in Rwanda and understand how the certified seed production and the seed management was carried out by farmers considering the current seed policy.

Data was collected in the Nyabihu, Musanze, Rubavu and Burera districts from the end of June to the end of September 2016. In order to gather the agronomic and socio-economic data, formal-informal interviews with farmers and expert interviews were conducted.

Currently, the private sector is the principal actor involved in the minitubers production, having a market share of 71 % while the public one has a 29 % share. The actual production of minitubers could cover between 13–30 % of the Rwandan national demand. However, due to a potato seed leak along the certification process and to a lack of actors who multiply lower seed categories into upper ones, the same figure is not reflected into the actual production of certified seed, which represents 5% of the national required demand.

In conclusion, in order to supply Rwandan farmers with high quality seed, the formal and informal systems must be complementary and mutually dependent. The certified seed production must be combined with the development of strong and target linkages (e.g. farmer field schools) along with the informal seed sector. The promotion of the integrated-participative approaches in breeding, seed production and distribution would help to increase the complementary between the two systems.

**Keywords:** Agricultural policies, formal and informal seed systems, potato, seeds

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## Marketers Consciousness for Quality Loss Reduction: A Case from Maize Marketers in Ghana

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Quality conscious markets are crucial for a sustainable and integrated approach to post-harvest loss (PHL) reduction. Farmers in sub-Saharan Africa (SSA), where informal markets exist, have often assessed rewards for the supply of good quality grains as unattractive and insufficient. Such informal markets lack standard grades, thereby relying on subjective grading (which is individual and criteria specific) and aspects of visible quality loss (which is based on search and experience dimensions of quality), to determine the extent of quality loss during and after purchase. This study investigates consciousness for visible quality loss reduction among maize marketers, and consequently, the rewards that accrue to farmers, following a case study approach in two districts in the Brong-Ahafo region of Ghana. Grain acceptability and the value placed on visible quality loss reduction are proxies used to assess quality consciousness. Assessment is based on two scenarios – the first is the current market situation based on subjective grading; while the second scenario involves the use of a hypothesised grade to capture potential premiums in a situation where defined grades are to exist. Data was collected through in-person interviews using structured questionnaires, and responses from 288 marketers were used for the study.

With subjective grading, marketers' acceptability of poor quality grains is assessed as low (44%), however, with the hypothesised grade; results show that the number of marketers willing to accept grains with high visible quality loss (VQL) almost doubled. Also, the subjective grading scenario shows a price overlap for both good and poor quality grains. Both results of the disparity in acceptability between the two scenarios and the price overlap in the current market scenario highlight the effect of subjective grading in markets, which results in the difficulty in exactly differentiating quality loss levels and consequently estimating incentives for better quality supply. Conversely, results from the hypothesised grade scenario show that where clearly defined standards or grades exist, marketers offer significantly different premiums on average over quality levels. Variables that describe collective action positively influence potential premiums for quality loss reduction. These results highlight the importance of standard grading systems and market groups in maize quality loss reduction.

**Keywords:** Ghana, maize, marketers, quality loss reduction, value

## Filling Institutional Voids: Role of Social Networks in Horticultural Market Access, Evidence from Kenyan Smallholders

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Imperfect market information is a key challenge to market access among small scale farmers in developing countries. Small-scale producers are faced with limited access to formal institutional structures to facilitate functioning markets. This is due to the minimal role played by the public sector in transmitting price information and developing market linkages. Social networks have been found to play a key role in filling formal institutional voids through facilitating adoption of technologies and innovations. However, what role do social networks play in access to market information, particularly for perishable crops? How does the market information from networks translate into market access? To answer these questions, the paper applied social network analysis using mixed methods approach. A household survey was conducted in 2015 followed by an in-depth qualitative study on selected farmers, traders and organisations. First, we mapped egocentric market information networks for small-scale vegetable producers. Second, we assessed frequency and reliability of market information through various network ties. Finally, we assessed challenges and opportunities of different network ties in access to markets. Graphs and measures of network structures were analysed quantitatively using UCINET 6 while challenges and opportunities of the network ties were assessed qualitatively using MAXQDA 12. Preliminary findings show that organisational ties, particularly civil society organisations offered novel market information; although, their ties to producers were minimal. Information transferred was infrequent and mainly targeted to a section of farmers, specifically group leaders who were core periphery nodes in the network. Spread and dissemination of market information was mainly through farmer groups and association members (bridging ties). Traders as bridging ties played a minimal role in transfer of market information. Bonding ties from family and relatives had higher density in the network but the information shared played a minimal role in market access. Issues of mistrust and jealousy were cited as challenges within bonding ties. Generally, the challenges cited by producers in utilising market information for market access were: ascertaining timeliness of market information; risks and related transaction costs particularly in potentially new markets.

**Keywords:** Horticulture, institutions, market access, social networks

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## Does Fair Trade Certification Improve Farmworkers' Welfare and Empowerment? Evidence from Nicaragua and Brazil

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Since the 1940s, Alternative Trade Organisations (ATOs) have been spreading all around the globe, in order to find new trade and marketing channels to commercialise fair trade goods, with the goal of contributing to a more sustainable development of agriculture and to the increase of rural well-being. Fairtrade (FT) is one of the most well-known Alternative Trade Organisations (ATOs). It originally aimed to create empowerment among small producers and improve their livelihoods. In 2011, FT USA started certifying coffee estates, in order to include also farmworkers into a new certification scheme, known as Fair Trade for All (FT4ALL). Through the data collected by the centre for tropical agriculture (CIAT) in Brazil and Nicaragua, we conducted an analysis to answer the following questions: (1) what is the causal effect of FT4ALL on workers' welfare? and (2) is FT4ALL effective at empowering farm workers? As result variables, we built two multidimensional indices: an index of welfare composed of 40 variables grouped into five dimensions and an index of empowerment which includes seven dimensions and 17 variables. This allows us to look at FT4ALL impacts from different perspectives: economic, to see if the model boosts incomes, increases assets and improves house quality; social, to assess the improvements in quality of life; empowerment, to determine workers' inclusion in farm organisational life and relationships within the farm.

We measured the average treatment effect of the certification through the implementation of the Ordinary Least Square (OLS) model, Propensity Score Matching (PSM) and Difference-in-Differences. Our results suggest that the certification has a positive effect on both workers' empowerment and welfare, both in Nicaragua and Brazil. The improvement in welfare is mainly due to increased access to education and healthcare services, as well as improvement of house quality, reached through the investment of a price premium received from estates from the sale of Fair Trade coffee. As for empowerment, most workers had become more involved in organisational life and gained greater access to training, albeit we found a negative effect on the dimension working environment.

**Keywords:** Coffee certification, empowerment, fair trade, farm workers, welfare

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## Determinants of Smallholder Farmer Market Choices: A Case of Organic Pineapple Markets in Uganda

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Organic pineapple production in Uganda is driven by the premium price in the export market. A market chain has developed with organically certified farmers selling to export companies. Whereas sometimes farmers fall short of the demanded quantities, the companies in some cases do not buy all the farmers' produce. This market failure often disadvantages the farmer whose primary objective is benefiting from the premium price. The study examines farmers' alternative market choices for organic pineapple and factors that influence those choices. Inability of export companies to procure all that farmers' produce particularly during peak seasons, and the organic market fixed prices that are sometimes lower than conventional market prices during lean periods is of concern. Consequently, farmers have a decision-making challenge regarding selling organic pineapples to the conventional markets. In the absence of empirical knowledge on factors that influence farmers' market choice, it is a challenge to accordingly advise the non-homogeneous organic farmers whose decisions may not be uniformly rewarding. This study was done in Kayunga and Luwero districts in central Uganda, purposively selected for being the leading pineapple producers. Using a cross-sectional household survey, data were collected from 275 randomly selected farmers (116 organic and 159 conventional). Organic farmers' market choices were categorised as (1) only organic market – farmers selling to export companies and (2) both organic and conventional – selling a portion to organic market and another to conventional market. The data were analysed using a Logit model (for organic farmer market choice decisions) and a Probit model to establish if both organic and conventional farmers are influenced by similar factors while transacting in the conventional market. Descriptive results show that the majority (68%) of organic farmers sold pineapple to both organic and conventional markets. Logit model results indicate pineapple-farming experience ( $p < 0.05$ ), annual pineapple harvests ( $p < 0.05$ ), and pineapple price in the conventional market ( $p < 0.01$ ) as some of the key factors influencing organic farmers' market choice. Annual pineapple harvests and the distance in kilometers between pineapple fields and the markets are some of the significant factors from the Probit model assessment.

**Keywords:** Market choice, organic pineapple, Uganda

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## Comparison of Ecosystem Services Value of Conventional and Organic Farms in Fariman City, Iran

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Valuation of ecosystem services is one of the most effective ways to focus on these services and helps planners to adopt appropriate approaches to sustain such services. Although organic farming concentrates on maintaining and protecting the ecological balances of agro-ecosystems, the share of organic agriculture is insignificant in Iran (less than 1 %). Therefore, the present study aims to evaluate the value of agro-ecosystem services under two different conditions - conventional and organic management - in Fariman city.

In this research, agro-ecosystem services were divided into two main groups; market services (primary and secondary production) and non-market services (pest control, soil production, carbon sequestration, supply of nutrients from the soil and soil fertility). Also, there were two main products (tubers and seeds using and harvested crops). The crops for home consumption were considered as economic value of secondary production.

The value of market and non-market ecosystem services in conventional and organic farms was evaluated according to three different scenarios. In these scenarios it was assumed that 10 %, 25 % or 50 % of the conventional farm area (total cultivated area of wheat was 10.000 ha and of potato 800 ha) would be replaced by an organic system. Finally, the differences between these scenarios were compared to the existing situation.

From the results, conventional potato system had a higher market value than the organic system, but the value of non-market services in the conventional system was less than the organic one. Market and non-market values for wheat organic farms was higher than conventional farms. So, the total value of ecosystem services in organic and conventional systems were about 260 and 106 \$ per ha and year, respectively.

Results illustrate that the value of non-market services rises along with the increasing area of organic farms. When 50 % of the farm area is cultivated under organic system, total non-market values of potato and wheat will reach to 22960 \$/year and 186613 22960 \$/year, respectively. Finally, according to the results and obtained benefits, developing and promoting organic agriculture in Iran is extremely recommended.

**Keywords:** Market value, non-market value, organic agriculture, valuation

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## The Challenges of Producer Organisations in Impacting Smallholders' Productivity and Commercialisation: Evidence from Ethiopia

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Previous studies suggest that the impacts of cooperatives involved in staple crops marketing in Africa on smallholders' commercialisation is very modest. Moreover, the management of these organisations is weak, membership rates are low and the organisations are financially constrained. In this study, we use panel data collected in 2012 and 2014 from Ethiopia to further disaggregate the impacts of market-oriented producer organisations to explain why the impacts are weak and its implication on financing and long term competitiveness of the cooperatives. Unlike previous studies, which studied only the impacts of membership, we distinguished village, member and transactional level impacts.

The result indicated that the most significant positive effect of the FMOs under study is village level impact. All farmers in the village where the FMO is present benefit from a competitive market created by the cooperatives. Specific benefits to members are weak and insignificant for the outcome variables under study. This indicates that FMOs in Ethiopia are caught in the efficiency (becoming important market actor) and equity (serving all the people in the village) dilemma, which has resulted in insignificant exclusive benefit to members who would potentially invest and improve the efficiency of the organisations. Furthermore, two major insights are drawn from the findings. First, studies comparing members with non-members from different villages lead to biased measurement of membership benefits since a village community, irrespective of membership, may benefit from the FMO's operations through increased competition at the local market level. Thus, all reported benefits of membership in previous studies are rather benefits of increased competition at the village market level triggered by the introduction of FMOs. Second, the results confirm that the present organisational structure does not provide incentives to become member or to make voluntary investments in FMOs. This further deteriorated the resource constraints the FMOs are facing.

**Keywords:** Africa, commercialisation, Ethiopia, marketing cooperatives, members willingness to invest, producers organisations, smallholders

## Alternative Food Systems: Using Space, Time, Integration and Rules as Narratives for Sustainability Transitions

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Considering the urgent need to make food systems more sustainable, alternative food systems (AFSs) are seen as starting points for sustainability transitions in the wider agro-food arena. AFSs include a wide array of food systems that are different from and more sustainable than the ‘conventional’ or ‘industrial’ ones. However, the literature often employs the term ‘AFS’ without further differentiation – we propose that by developing intuitive categories to describe AFSs, we can create more powerful narratives to support AFSs with transformative potential. This review proposes a novel categorisation of AFSs derived from an overview of their history and movements that shaped them. We propose to categorise AFS along four systemic attributes: space, time, integration and rules. It should be highlighted that these attributes are not mutually exclusive. The space attribute refers to the fact that AFSs tend to be more small-scaled, localised and horizontally integrated – examples include community-supported agriculture, farmers’ markets, farm food outlets, box schemes, farm to school programs, or local public procurement initiatives. A second attribute is time; emerging AFSs have put an emphasis on giving food enough time to grow, to be prepared with care and to be enjoyed in a social experience (e.g. the Slow Food Movement). A third attribute is integration; a broad family of AFSs (e.g. organic and biodynamic agriculture) were inspired by the science of agroecology – thus attempting to increase the integration of agroecosystem elements. A fourth defining attribute of AFSs is the attempt to change the rules and institutions that govern the interaction of value chain actors. Some initiatives (e.g. Fairtrade) have focused on the adaptation of trade linkages towards social justice and empowerment. Others, such as the food sovereignty movement promoted by La Via Campesina and local food cooperatives, are more radical and transformative.

We believe that referring to space, time, integration and rules, offers a unique opportunity to create simple, compelling narratives for promoting transition in food systems. Such narratives are needed to guide strategic support for initiatives with genuine transformative potential and/or ambition. We propose to explicitly test the proposed narratives in a multidisciplinary and transdisciplinary setting.

**Keywords:** Agroecology, alternative food systems, food sovereignty, local food systems, organic farming, slow food, sustainability transitions

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## **Sustainable Agriculture Models and Willingness to Pay (WTP): A Matching Approach among Consumers in Kenya**

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The markets for organic products are emerging as an alternative to health conscious consumers in the world. On the other hand, different scholars and organisations have promoted models of sustainable agriculture to improve on the consumption of organic products. For example the “Save and Grow” model promoted by Food and Agriculture organisation (FAO). However, the purchase of organic vegetables among urban households, remains at minimum levels. Moreover, few studies have attempted to evaluate the factors that affect perception of sustainable agriculture models for organic vegetables among urban households. Furthermore, the specific impact of perception of “Save and Grow” model on the WTP has not been widely evaluated by researchers. Therefore, we evaluated the determinants of adopting “Save and Grow model” for organic vegetables among consumers in Nairobi. Secondly, we also assessed the impact of “Save and Grow” on WTP for organic vegetables among consumers in Nairobi. The survey collected data from 308 consumers in Nairobi, Kenya. We selected the consumers based on a systematic random sampling approach. This involved sampling every 5<sup>th</sup> consumer at the exit of the retail outlets. We used a pretested questionnaire to collect data at exit points of the main organic outlets in Nairobi. The questionnaire contained questions on the consumers’ socioeconomic characteristics. Moreover, the consumers were asked about their willingness to pay for organic vegetables. Subsequently, we analysed the data using a propensity score matching. The results suggest a significant relationship between perception of “Save and Grow model” and the following socioeconomic characteristics: health, gender, employment status, education level, price and labeling. Moreover, the “Save and Grow” had a significant impact on WTP for organic vegetables among consumers. We concluded that sustainable agriculture intervention is an avenue for transitioning from conventional to organic products. Marketers of organic products can focus on this avenue in promotion of their products in the urban markets. Policy should focus on up-scaling the “Grow and Save” model which may accelerate on embracing of organic products in the urban centres.

**Keywords:** Consumers, education, products, save, survey, vegetables

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## Implications for Linking of Smallholder Farmers to Markets: Role of Social Capital

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Social capital provides insights on the social bonds and norms in a society. This study empirically investigated the dimensions of social capital (bonding, bridging and linking) that have potential in enhancing the performance of Indian smallholder vegetable farmers. The research analysed dimensions of social capital and their influence on the market preferences which in turn influences their livelihood. A survey of 100 randomly selected smallholder farmers who were transacting in cooperative regulated or conventional market, has been conducted. The social capital statements representing three dimensions of social capital were coded on the five-point Likert scale with increasing level of agreement. Further, when subjected to principal component analysis (PCA) these statements were reduced to four components (informal networks, collective action, formal networks, institutional trust), whose scores are used as social capital explanatory variables in ordered probit regression to compare the preferences across three coexisting markets. There is a significant difference between the social capital among cooperative farmers, regulated farmers, and conventional farmers. Further, our research findings indicate that the components of social capital, informal networks, collective action and institutional trust greatly influence the farmers higher preference for cooperative markets. Collective action decreases the preference for regulated market and institutional trust decreases the preference for conventional marketing. Thus strengthening the social capital can be a powerful way for improving inclusiveness of farmers to high coordinated value chains such as cooperatives. Increased trust in formal institutions reduces the chance of farmers being exploited by conventional traders. The practical implication of this study is that efforts should be made to build the social capital among the farmers by developing research approaches and bottom up strategies where farmers can involve in high value coordinated value chains through collective action. The significant and positive relationship between the social capital and cooperative marketing is a pathway for better status when the social relations are promoted and operated in a sustainable manner. As smallholder farmers are constrained by resources such as land, labour and capital, there is an increased scope for enhancing the social capital and also encourage them to act collectively to improve their livelihood.

**Keywords:** Ordered Probit regression, principal component analysis, smallholder farmers, social capital

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## Assessment of the Baobab Processing and Exporting Industry in Southern Africa

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The pulp from the fruit of the baobab tree (*Adansonia digitata* L.) is getting increasingly popular as a food ingredient on both a local and international scale due to its particular nutritional properties. By adding value to the resource through processing baobab has the potential to generate much needed income and lift rural communities in sub-Saharan Africa out of poverty; however, increased export of the resource may also threaten the livelihoods of local populations and lead to overexploitation of natural baobab stands. More information on the sustainable commercialisation of baobab resources is, therefore, needed. The current paper presents preliminary results of an ongoing research project. Innovation system analysis provides the framework to characterise the developing baobab processing sector in detail, since it encompasses the complex set of relationships amongst different actors in the system (e.g. enterprises, research institutes, authorities, consumers, etc.) as well as influencing factors such as laws, policies, standards or social norms. Analysis focussing on the baobab exporting industry in Southern Africa have been conducted to help better understand the structure and boundaries of the sector, involved agents and their interactions, innovation and production processes, sector transformation and the factors at the base of the differential performance of firms in the sector. Baobab processing initiatives from selected countries of Southern Africa (Malawi, Zimbabwe, South Africa, Mozambique, and Tanzania) have been assessed, highlighting small-scale commercial enterprises reaching high-value international markets. These enterprises often derive from development initiatives and feature not only economic but socio-economic goals in their overall strategy and act in an environment characterised by both competition as well cooperation dynamics (co-opetition) to achieve better collective and individual results. This makes them particular interesting cases on whether and how high-quality products for international markets can be produced while contributing to socio-economic development across the supply chain.

**Keywords:** Baobab (*Adansonia digitata* L.), co-opetition, commercialisation, food processing, innovation system analysis

## Market Survey of *Garcinia kola* (Bitter Kola) Seeds in Yaoundé City, Cameroon

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*Garcinia kola* (Bitter kola) is a medicinal plant species, whose seeds are collected in the forests of sub-Saharan Africa mainly for subsistence and used as a treatment for stomach ache or as a stimulant. A little is known about the nutrition composition, domestication or market chain development of bitter kola. The seeds are however commonly traded at local markets and even attract the attention of consumers abroad. Thus, the aim of the survey was to document who were typical sellers of bitter kola seeds and what marketing practices they used. During June and July 2016, we initiated a survey in the streets of four different districts of Yaoundé city with increasing distance from the centre in order to identify suitable markets and respondents. Total number of 36 street vendors and 35 market-traders were interviewed via semi-structured questionnaires. Street vendors could be further divided into street mobile-vendors (24), predominantly boys (95.6%) with average age of 15.6 ( $\pm 3.16$ ) years, selling seeds close to the main streets to taxi drivers to cover their school fees, and stall-holders (12), mainly women (58.3%) of average age 38.5 ( $\pm 7.56$ ) years, situated far from main communications and selling seeds to passing-by people. Market-traders were again particularly women (86%), 49.9 ( $\pm 9.92$ ) years old, selling bitter kola to a very diverse group of customers, similarly to stall-holders. Nevertheless, different selling units were observed among both types of vendors, i.e. street vendors used three seeds at an average price of 100 FCFA (€0.15), while market-traders used mainly cups for 500 FCFA (€0.76) each. Majority of all vendors (87.5%) sold seeds because of their medicinal ability. Selling bitter kola seeds represented good opportunity for targeted vendors, which could explain why most of them came from the same region as the majority of seeds. Collector survey points played an important role as 54.8% of respondents purchased bitter kola from them, while all street vendors were buying the seeds from market-traders. Further studies should document whole value-chain, including consumer preferences, domestication and the role of middlemen.

**Keywords:** Mapping of market chain, medicinal plants, non-timber forest products, vendors

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## Internationalisation Paths of Chilean Fruit Export Companies: Are They Regionally or Globally Oriented?

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In the past, big multinational companies from developed countries dominated the agricultural world markets. Thus, research on internationalisation strategies focusses mainly on these firms. In the literature, there is a continuing debate regarding firms' internationalisation pathways and the definition of "global company" resulting in controversial approaches for firm categorisation. Simultaneously, Aggarwal et al. (2011) developed with their matrix of multinationality a rather inclusionary approach. Nowadays, however, showing a rapid export growth, firms from emerging economies have become key players in the world export markets, increasing their importance. Our research contributes to the existing literature by studying companies from the agricultural sector in Chile as a prime example of emerging economies from Latin America, which has not been covered by the conceptual literature yet. We conduct a longitudinal analysis for a period of 7 years (2009–2015) to examine the changes in the internationalisation strategies of a sample of 233 fresh fruit exporters in Chile to determine their internationalisation level. To do so, we adapt and extend the matrix of multinationality developed by Aggarwal et al. (2011) to classify firms according their internationalisation level. We use secondary data from Eximfruit database, which contains the distribution of Chilean fresh fruit exports to different geographic regions. With 65.12 % of the firms being classified as transregional, 16.06 % as global, 12.75 % as host regional and 6.07 % as regional, results of our empirical study indicate that the most employed internationalisation strategy is the transregional. Most of the fruit export companies in Chile follow a pattern of incremental internationalisation, with periods of internationalisation and de-internationalisation. Firms mainly prefer to extend (and contract) their market scope in one single geographic region per year, which could indicate some liability of inter-regional foreignness in the internationalisation process. We confirm the broad triad region (North America, Europe and Asia) as the most important market in the world, even for emerging economies located out of these regions. Simultaneously, the home region becomes increasingly important in the last years, especially for the more internationalised firms. However, it is still not fully penetrated by most of the firms, regardless their internationalisation level.

**Keywords:** Emerging economies, internationalisation, Latin America

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## Are Thai Consumers' Willing to Pay More for Local Fair Trade Rice

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This research aimed to investigate the feasibility to develop Fair Trade certified system specifically for Thailand under “Fairtrade Thailand” label by analysing consumers’ perception toward the Fair Trade concept and willingness to pay for different types of certified labels on 5 kilogram Thai Hom Mali (Jasmine) bag rice. The analyses were based on data collected from 407 samples of Thai Hom Mali bag rice consumers in Bangkok. In order to know the impact of knowledge about certified labels on willingness to pay, two formats of questionnaire were used: explaining the meaning of labels before and after completing the choice tasks. The base case (status quo) was Thai Hom Mali bag rice with Thai Hom Mali standard guarantee label. The mixed logit model was used for analyses.

The results showed that consumers have a lack of understanding about existing certified labels. Only Thai Hom Mali standard guarantee label was known by the majority of consumers (58 %). The majority of consumers supported the “Fairtrade Thailand” certified label idea. Consumers were willing to pay 20 % premium for Thai Hom Mali bag rice with “Fairtrade Thailand”. Without Thai Hom Mali standard guarantee label, the price for a bag of rice dropped by 19 % compared to the base case. For one who cannot differentiate between “Organic Thailand” label and Good Agricultural Practice “Q” label, the willingness to pay for “Organic Thailand” label was 12 % which was not significantly different from the willingness to pay for “Q” label with 7 % of the consumers in this study. For consumers knowing the meaning of both “Organic Thailand” label and “Q” label, the willingness to pay for “Organic Thailand” label increased to 22 % which is much higher than the willingness to pay for “Q” label of 8 %.

Based on these findings, it is feasible to develop a Fair Trade certified system specifically for Thailand under “Fairtrade Thailand” label since the majority of consumers agreed and supported this concept. However, one of the most important things to do is to find a way to disseminate and to educate consumers about the “Fairtrade Thailand” label as well as on other existing certified labels, in order to increase the value of high standard products.

**Keywords:** Bag rice, fair trade, mixed logit, Thailand, willingness to pay

## Impacts of Improved Chickpea Adoption on Smallholder Commercialisation in Ethiopia

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Enhancing agricultural productivity through the adoption of proven technologies presents a credible pathway to economic development and poverty reduction. The adoption of improved chickpea varieties have the potential to contribute not only to food security but also to economic growth and development as well as poverty reduction among the poor, since the adoption of such improved varieties are both pro-poor and environmentally friendly. Chickpea serves as a source of proteins and nutrients for poor households with the improved varieties having a very high value with potential for export. We therefore analysed the impacts of improved chickpea adoption on smallholder market participation and market integration employing a panel analysis of three rounds (2008, 2010, 2014), drawn from 606 households in potential chickpea producing areas in the Shewa region of Ethiopia. The decision to adopt improved varieties is potentially endogenous on small market participation and market integration as well as other observed or unobserved characteristics. The problem of selection bias is addressed by estimating a correlated random effect (CRE) panel models for commercialisation regression using a multiple instruments. Instrumentation is carried out using a control function (CF). A Double hurdle model is specified to estimate commercialisation wherein the first hurdle tackles the decision to participate or commercialise using a probit maximum likelihood estimator while the second hurdle specifies the intensity of market participation or commercialisation using a truncated normal regression model. From this study, it is expected that the adoption of improved chickpea varieties will increase by more than 70 % across the three panel data rounds. Adoption of chickpea varieties will drive both commercialisation decision and the degree of commercialisation at a less significant rate as a result of the food security issues in Ethiopia. Accordingly, labour force is expected to be positively correlated with both outcomes of commercialisation since a more active labour force implies higher production and therefore market participation. This study therefore affirms the importance of improved chickpea varieties for commercialisation and thus provides support for policies targeting poverty alleviation in rural areas.

**Keywords:** Adoption, commercialisation, Ethiopia, improved chickpea

# Value chains

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## Oral Presentations

- SHAMS UL HAQ, AYE MOE SAN:  
**Logistics-Centric Supply Chain Approach for Pakistan Mango Export to Europe Market: Discrete Choice Analysis** 454
- BENARD OTIENO ABEL, DIVYA RAJANNA:  
**Value Chain Governance of African Indigenous Vegetables: Smallholders Participation in Kenya** 455
- MANUEL DIAZ, KAREN ENCISO, ANDRÉS CHARRY, JHON JAIRO MUÑOZ QUICENO, LISBETH ROCIO RUIZ, CRISTHIAN DAVID PUERTA RODRIGUEZ, NELSON JOSÉ VIVAS QUILA, SANDRA MORALES VELASCO, NOE ALBAN LOPEZ, MICHAEL PETERS, STEFAN BURKART:  
**Analysis of the Legal Framework for the Colombian Cattle Value Chain** 456
- TATU MNIMBO, JOYCE LYIMO-MACHA, JUSTIN KALISTI URASSA, KHAMALDIN DAUD MUTABAZI, STEFAN SIEBER:  
**Gendered Analysis of Asset Ownership and Participation in Market Oriented Crop Value Chains** 457
- MARCELO CUNHA:  
**Sustainable Resource and Market Access: Towards an Enabling Institutional Environment along the Value Chain of a Non-Timber Forest Product in Amazonia?** 458

## Posters

- AKALU TESHOME, JOCHEN DÜRR:  
**Value Chain Analysis of Vegetable Crops: The Case of ‘Yayu’ Biosphere Reserve Area of Ethiopia** 459
- JAN VAN DER LEE, BOCKLINE BEBE, SIMON OOSTING:  
**Sustainable Intensification Pathways for Dairy Farming in Kenya** 460
- JHON JAIRO MUÑOZ QUICENO, LISBETH ROCIO RUIZ, KAREN ENCISO, CRISTHIAN DAVID PUERTA RODRIGUEZ, MANUEL DIAZ, ANDRÉS CHARRY, JHON FREDDY GUTIERREZ SOLIS, NELSON JOSÉ VIVAS QUILA, SANDRA MORALES VELASCO, NOE ALBAN LOPEZ, MICHAEL PETERS, STEFAN BURKART:  
**Bottlenecks for the Sustainable Development of the Beef Value Chain in the Colombian Cauca Department** 461

- ZOLTÁN M. FERENCZI, WOLFGANG BOKELMANN, SILKE STÖBER:  
**Inclusive Value Chain Development through Evidence Based Targeting of Actors** 462
- AYE MOE SAN, SHAMS UL HAQ, YEE MON AUNG:  
**Performances of Private Rice Specialisation Companies in Myanmar Rice Value Chain** 463
- KAREN ENCISO, AURA BRAVO, ANDRÉS CHARRY, JHON JAIRO HURTADO, MATTHIAS JÄGER, STEFAN BURKART:  
**Participatory Development of Sector Strategies for Double-Purpose Cattle Value Chains in Caquetá and Guaviare, Colombia** 464
- YEE MON AUNG, THEINGI MYINT:  
**Analysis of Pulses Industry Value Chain in Bago and Mon State, Myanmar** 465
- ANDRÉS CHARRY, MATTHIAS JÄGER, JHON JAIRO HURTADO:  
**Multi-Stakeholder Platforms for Value Chain Upgrading. The Case of Cocoa in the Colombian Amazon** 466
- HAZAL AKÇAKARA, TINA BEUCHELT:  
**Do Palm Oil Sustainability Certifications Deliver their Promises? A Review** 467
- ANN-KRISTIN VON SAURMA-JELTSCH, MARGARETA LELEA, BRIGITTE KAUFMANN:  
**Enhancing Skill-Sharing within Multi-Stakeholder Processes: An Example from the Small-Scale Dairy Chain in Kenya** 468
- KATHRIN MEINHOLD, YAHIA OMAR ADAM GUMA, JOYCE CHEPNGENO, MUNTHALI CHIMULEKE, ESTHER EVANG, JENS GEBAUER, TSIGE-YOHANNES HABTE, MARTIN HOMMELS, GEORGE KINYUA KAIMBA, MICHAEL KRAWINKEL, FLORIAN KUGLER, TARIG ELSHEIKH MAHMOUD, NYORI JEREMIAH MBUGUA, KAVOI MUTUKU MUENDO, JOHN BOSCO MUKUNDI, ANTHONY MAINA NJIRU, WILLIS OMONDI OWINO, FREDAH KARAMBU RIMBERIA, EL AMIN SANJAK, MARTIN SCHÜRING, MUNEEER ELYAS SIDDIG, ARTHUR STEVENS, MOHAMED EL NOUR TAHA, ANDREAS TRIEBEL, DIETRICH DARR:  
**Collaborative Product Development to Enhance Local Food Security and Livelihoods in Eastern Africa** 469
- STEFANNY QUIÑONES, AMANDA NOGUERA, SILVIO ANDRÉS MOSQUERA, NELSON JOSÉ VIVAS QUILA, SANDRA MORALES VELASCO, JHON JAIRO MUÑOZ QUICENO, STEFAN BURKART:  
**The Impact of Management Practices on Pre-Mortem Meat Quality along the Colombian Cattle Value Chain** 471

AMANDA NOGUERA, STEFANNY QUIÑONES, SILVIO ANDRÉS MOSQUERA, NELSON JOSÉ VIVAS QUILA, SANDRA MORALES VELASCO, JHON JAIRO MUÑOZ QUICENO, STEFAN BURKART: <b><i>Post mortem</i> Management and Microbiological Presence as Quality Factors along the Beef Value Chain in Colombia</b>	472
HUNG ANH NGUYEN, WOLFGANG BOKELMANN, NGO THI THUAN, NGUYEN VAN MINH, DO THI NGA: <b>Strengthening the Linkages Between Farmer Producer and Manufacturer in the Coffee Value Chain of Daklak, Vietnam</b>	473
NARILALA RANDRIANARISON, HERIMIHAMINA ANDRIAMAZAORO, SOLOFO SAMBATRA TOLOJANAHARY: <b>Limiting Factors in the Development of Vegetable Value Chains in Southeastern Madagascar</b>	474

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## Logistics-Centric Supply Chain Approach for Pakistan Mango Export to Europe Market: Discrete Choice Analysis

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Pakistan with mango as its 2<sup>nd</sup> major export fruit and 4<sup>th</sup> largest producer in the world is still facing serious constraints in its export marketing. Having said all about the issues and challenges related with the production and domestic infrastructure, perishable nature of the product like mango makes its exporters more sensitive to have improved supply chain to access distant but high value markets like Europe.

This study based on the fact that international freight charges account for almost 70 % of total export cost, is hypothesised that improved transport in terms of cost and value can be a commercially attractive proposition for the traders. Logistics oriented supply chain derived from transaction cost theory is supposed as the theoretical foundation of the research. Primary data of the 100 grower cum exporters, sole exporters and 30 shipping companies like air and sea lines collected during a field survey in 2014 has been employed for the analysis. Sea-freighting has been compared with the current mode of transportation (air) as a future alternative mode. Discrete choice modelling technique is used as a methodological tool after identifying attributes of transaction cost, travel time, loss & damage, frequency and compensation during the focus group discussions.

In the results, findings of different mixed logit models of mode choice reveal that air transport is costly but more safe. Though sea-freighting is found 3 to 4 times cheaper than air but yet it's highly sensitive as it takes around 27 days for shipment from Pakistan to Europe. Factors like transport cost, travel time, loss & damage and compensation are found significantly affecting overall shippers' mode choice behaviour. For future, exporters perceive that if somehow high percentage of loss and damage in sea-shipping is reduced with the provision of high-tech containers; they will be willing to adopt sea transport on regular basis.

The authors conclude that along with the provision of domestic facilities like processing plants and certification procedures; logistics oriented supply chain policies introduced by public and private sector can equally enhance export of perishable commodities to far-reaching markets.

**Keywords:** Discrete choice modelling, Europe, logistics, mango, mixed logit, Pakistan

## Value Chain Governance of African Indigenous Vegetables: Smallholders Participation in Kenya

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Production and marketing of African indigenous vegetables (AIVs) offers opportunities for smallholders to participate in higher value chains in Kenya. There is growing demand for AIVs among the middle and upper-class urban consumers due to promotional campaigns by research organisations and public agencies. The vegetables are rich in macro and micronutrients and possess bioactive compounds with antioxidant potential making them very suitable for food and nutritional security. Production of AIVs is predominantly by smallholders in rural and peri-urban areas in Kenya. These vegetables are now sold in big supermarkets signalling prospects for the smallholder to participate in coordinated higher value chains. Access and participation in these higher value chains depend on the embeddedness in the coordination and governance structures. Based on an exploratory multiple case study, this paper comprehensively maps out chain actors and their activities, assesses the coordination and governance structures that influence participation in the AIV value chains in Kenya. It further identifies constraints and opportunities for integration and finally explores upgrading strategies for sustainable smallholders' participation. A comparison has been made between governance coordination in the traditional and coordinated value chains for rural and peri-urban smallholders. A stratified multistage sampling technique was used to select a sample of 288 respondents and data was collected through semi-structured interviews using different instruments for different nodal actors. A majority of farmers (98 %) participate in traditional value chains as compared to only 2 % that supply supermarket which represent coordinated value chains. The study did not find collective actions for marketing indigenous vegetables among rural farmers. There were no direct transaction relationships between rural farmers with the more remunerative urban traders and supermarket outlets. Farmers in the peri-urban areas made use of farmer groups to participate in urban wholesale markets as well as supply supermarket outlets. The wholesalers and supermarkets set compliance parameters such as price, quality and quantities in the traditional and coordinated value chains respectively. Vertical linkages between value chain actors in both coordinated and traditional value chains are weak; mostly characterised by "arms-length" market transactions, except for the modular governance arrangements exhibited between supermarkets and their suppliers.

**Keywords:** African indigenous vegetables, chain governance, coordinated value chains, smallholder participation, traditional value chains

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## **Analysis of the Legal Framework for the Colombian Cattle Value Chain**

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The legal framework for the cattle sector can also be considered as public policy for its development. This can be understood as a set of incentives and sanctions, which influences the affected actors and generates changes, not only in internal behaviours and dynamics but also in values. In 2003, Colombia's legal framework for the cattle value chain saw the beginning of a period of major transformations, but it was in 2007 when a radical and complex legislation was presented to introduce the cattle sector into the context of international trade. However, the expected changes of behaviour among actors were not fully achieved by as incompliance could and still can be observed throughout the sector.

This study was conducted in 2016 and has the aim to revise the legal framework for the Colombian cattle value chain and to a) analyse the underlying complexities that came with the implementation of rigid legislative processes, and b) to identify the bottlenecks considering the aim of putting the cattle sector into a global context. The methodology consists of two steps: 1) a systematic and chronological compilation of the laws, decrees, resolutions and standards, and 2) an analysis of both the institutional and social evolution of the sector over time, as well as the advances and challenges presented in terms of e.g., traceability, hygiene, animal welfare and sustainability.

First results show that although important advances have been made in order to adapt the legal framework to international requirements, these are not sufficient when adequate enforcement and control mechanisms are missing. In addition, the success of public and legislative policies depends to a great extent on the context in which they are applied and the capacities actors have to understand their complexity.

This study will serve decision makers in the development of targeted follow-up and improvement processes in order to ensure future competitiveness and sustainability of the cattle sector at international level. It will also serve the value chain actors as guidance on the rules that apply for their specific activity – a valuable source of information given the fact that official information sites are often incomplete.

**Keywords:** Competitiveness, international trade, livestock, policy analysis, public policy

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## Gendered Analysis of Asset Ownership and Participation in Market Oriented Crop Value Chains

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Gender inequalities in asset ownership result in different levels of participation, methods of production and modes of marketing cash crops, and bear consequences for women's potential outcome in the cultivation of these crops. Assessing gender participation in cash crop production is important, not just because it differs from the production of other crops, but because cash crop production holds significant potential as a means by which rural households can improve their welfare. In many contexts, ownership of assets is strongly gendered, reflecting existing gender norms and limiting women's ability to invest in more profitable livelihood strategies such as market-oriented agriculture. Yet the intersection between women's asset endowments and their ability to participate in and benefit from agricultural interventions receives minimal attention. This study aimed at analysing the relationship between asset ownership and participation in markets oriented crop value chains. The specific objectives are 1. To analyse gender dynamics in crop commercialisation; 2. To assess the relationship between asset ownership and market participation. Results show that households with a good number of family labour are likely to participate in commercialisation. We also find a positive relationship between participation and value of durable assets, suggesting it is an important determinant in the decision to participate in commercialisation. Furthermore, we find that the degree of commercialisation is negatively associated with age and household size but positively associated with food security. The study concludes that asset ownership is significantly shaped by institutional factors such as social norms and the study observes the importance of complimenting resources such as labour and capital to be able to translate asset ownership into income generating output.

**Keywords:** Asset ownership, gender, market oriented crops, participation, value chain

## **Sustainable Resource and Market Access: Towards an Enabling Institutional Environment along the Value Chain of a Non-Timber Forest Product in Amazonia?**

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Given the lack of access of forest dependent rural dwellers to natural resources and markets as well as the lack of an enabling institutional environment for reconciling biodiversity conservation and livelihood strategies in the Amazon:

How do informal and formal institutions affect the access to Brazil nuts (BN) and markets by upstream actors of the BN value chain (VC) in the Lower Amazon region?

The informal institution analysed is the 'debt-peonage system' and the formal one is the 'Term of Compromise' (ToC) in Brazil. ToC is a legally-based instrument for overcoming conflicts between Brazil's Ministry of Environment (MMA/ICMBio) and traditional populations over natural resources in protected areas.

The analytical framework captures how both informal and formal institutions as well as related formalisation and institutionalisation processes affect the resource and market access by upstream VC actors. At the core of the analysis is the VC position of BN gatherers affected by both the processes of institutionalisation of limitations upon their access ability per debt-peonage and formalisation of restrictions upon their access rights per ToC. It is an innovative framework for inclusive sustainable value chain development (VCD) of agricultural and, especially, non-timber forest products in different rural contexts.

Quantitative and qualitative data were collected from 'community' to national level (2012–2015). A survey on socioeconomic conditions and resource access was conducted with 185 households in four municipalities of the Lower Amazon basin as were narrative, problem-centred and key-informant interviews with VC actors (BN gatherers and buyers), representatives of government (e.g. MMA/ICMBio) and NGOs.

Results indicate: (i) formalisation of resource and market access restrictions per ToC has reinforced unbalanced patron-client relations among BN gatherers and buyers already institutionalised per debt-peonage; (ii) self-reliant sustainable BN VCD depends on democratic participation in decision-making for locally adapted ToC by transforming the governance structures of councils for managing PAs from 'consultative' to 'deliberative' ones, while co-shaping a conducive context-sensitive institutional environment, policies and service provision; (iii) 'socioeconomic upgrading' of the position of upstream VC actors builds on ability and self-organisation of smallholders in 'well-managed' cooperatives. Finally, evidence-based policy 'suggestions' are provided for self-determined sustainable rural development.

**Keywords:** (Agro)biodiversity conservation, access ability, Amazonia, environmental governance, inclusive sustainable development, institutions, livelihoods, local markets, production networks, sustainable upgrading

## Value Chain Analysis of Vegetable Crops: The Case of ‘Yayu’ Biosphere Reserve Area of Ethiopia

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The study was conducted in Yayu and Hurumu districts of Illubabor zone, Ethiopia with the specific objectives of analysing vegetable value chain, examining the performance of actors in the chain, and identifying factors affecting vegetables market participation decision of smallholder farmers. Both quantitative and qualitative data were collected using different survey instruments. The quantitative data were generated from randomly sampled 330 producers, 25 traders and 16 consumers using structured questionnaire. Qualitative data were also collected from four farmer groups, 13 traders, 3 input suppliers, 11 consumers (including restaurants) and 7 experts and 2 development agents. The study revealed that the major actors in the study area are input suppliers, producers, collectors, wholesalers, retailers, consumers. Six marketing channels for vegetable crops were identified. The study identified different constraints related to vegetable production. The major constraints are: lack of nutrition-sensitive farming systems; pest and disease problems; high cost of seed; lack of high quality seeds; non-availability of chemical inputs; seasonal constrained production systems; competition with cash crops; lack of research and extension support; low productivity; low prices after harvesting; and non-availability of improved technology. The major constraints related to vegetable marketing are: the low volume of supply; seasonal non-availability of vegetables; fluctuations in price; problems with storage, processing and packaging (lack of post-harvest handling); lack of adequate market place; distance from market place; and shortage of capital. Lack of awareness of nutritional issues; low purchasing power; the high price of vegetables; and low supply of vegetables were identified as the major constraints related to vegetable consumption. The results of econometric analysis showed that market participation decision in vegetables market was significantly affected by age of the household head, sex, education, family size, irrigation access, non-farm income, access to input and extension, distance to the market and lagged price. Therefore, policy aiming at increasing farmers' access to modern inputs, developing and improving infrastructure, gender consideration and improving extension system are recommended to accelerate the chain's development.

**Keywords:** Econometric analysis, market participation, value chain, vegetables

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## Sustainable Intensification Pathways for Dairy Farming in Kenya

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This case study on dairy farming in Kenya illustrates how intensification takes shape within a given context – a context with various opportunities and constraints within which farmers have to make strategic management decisions on the future of their farms – and assess sustainability of this intensification. The study follows a bottom-up identification of sustainability indicators and sustainable intensification pathways. These are generated from interviews, augmented from literature, and structured in the MESMIS framework.

Land appears to be the most limiting production factor in the Kenyan highlands, while climate effects on production are most limiting in the coastal lowlands. Large differences in intensification are visible, with a variety of farming systems as a result. We show how farmers at different intensification levels in four selected case study areas can - or should – have different strategies for sustainable intensification, depending on their current land use intensity, access to external inputs and services, and the markets they trade in. The outcomes of a SWOT analysis inform coping strategy options for dealing with the major stresses and shocks affecting dairy farming. Strategies for sustainable intensification (SI) are then explored, identifying key SI challenges, SI choices and coping strategies for farmers.

Currently farmers choose between three intensification pathways: Connecting to the processed dairy supply chain, to niche chains for quality products, or to the local raw milk chain. The choice for particular (alternative) pathways depends on stakeholder goals, and on how one deals with the trade-offs between alternative pathways and coping strategies.

In strategy selection, trade-offs between economic, social and environmental sustainability parameters can make for big differences, where choices include ‘reducing cost of production’ vs. ‘retaining the smallholder mode of production’; ‘development for all smallholder members of dairy cooperative societies’ vs. ‘focus on entrepreneurial dairy smallholders’; ‘participating in the bulk processed milk sector’ vs. ‘developing ways to market milk locally’; ‘local nutrient-balanced systems’ vs. ‘traded feed and fodder with accumulation of manure’.

This case study informs research needs for sustainable intensification of dairy farming in Africa, split out by farming system-, value chain-, and sustainability issues.

**Keywords:** Dairy, farming systems, Kenya, sustainable intensification

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## **Bottlenecks for the Sustainable Development of the Beef Value Chain in the Colombian Cauca Department**

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The development of a competitive beef value chain for accessing formal and specialised national and international markets is among the principal goals of the Colombian agricultural development plans. However, cattle production in Colombia is very diverse in terms of e.g., climatic conditions, agro-ecological zones, farm sizes and production systems. This is influencing the nature of the aligned value chains and their potential for development and for accessing more sophisticated markets. While in some Departments (e.g., Córdoba) a stronger development and export orientation can be observed, in other Departments (e.g., Cauca) the beef value chains are rather characterised by their informality and limited access to formal markets.

In order to understand why the development is slower in the Cauca Department compared to others, a full in-depth value chain analysis was conducted with the goal to identify the most crucial bottlenecks for a sustainable development. Data was obtained between 2015 and 2017 for all direct and indirect actors along the value chain, by applying semi-structured surveys (>800), personal interviews with experts and value chain actors (15), and workshops (5). Data is currently being analyzed.

Among the expected results we will be able to show a complete map of the value chain, focusing on the strengths, weaknesses, opportunities and threats for each group of actors as well as for the value chain itself, and the external factors influencing the chain. This will help in identifying the major bottlenecks and possible strategies for achieving a stronger, sustainable and more market-oriented development of the value chain. The results will be of high relevance for the involved decision- and policy-makers and support them in the formulation of adequate development strategies and sector policies. The results will also be of relevance for the value chain actors, as the identified bottlenecks and strategies directly present opportunities for improving competitiveness.

**Keywords:** Cattle production, competitiveness, public policy, sustainability, value chain analysis

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## Inclusive Value Chain Development through Evidence Based Targeting of Actors

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Inclusive value chain development (VCD) approaches aim to improve linkages between retailers, intermediaries and smallholders in an attempt to raise chain performance or target individual actors, especially smallholder farmers in order to raise capacity that in turn should generate livelihoods for them. Often, however, there is no evidence-based targeting and differentiation between possible subgroups of smallholders or other actors even though research indicates that VCD interventions may only help smallholders participate in coordinated value chains if certain household characteristics are given. For one, smallholder households may require certain assets in order to successfully participate in the value chain. Also, the proximate socio-economic and policy environment may determine to a large extent if a household is able to benefit from the value chain or not (Horton, Donovan, Devaux, Torero 2016). This underlines a pressing need for a more comprehensive and differentiated understanding of the asset endowments and meso-level conditions of smallholder households for policy design, yet the empirical research is largely inadequate in this regard.

We argue that cluster analysis applied to large-N socio-economic panel datasets may help to identify the right target groups and in turn improve the inclusive-ness of value chain development approaches. The present work studies the characteristics of smallholder producers of African Indigenous Vegetables (AIVs) in Western and Central Kenya and the degree of similarity between them. The AIV sector has received prominence given the potential of these crops to reduce malnutrition. However, smallholders have been targeted with mostly little differentiation. Within the international research project HORTINLEA we have collected data from approximately 1000 smallholder producer households at various points in time. The clustering of the households was carried out based on variables that were derived using the conceptual framework of the livelihood approach because this approach integrates various endowments and also the institutional frame household participants of VCs operate in. Finally, we discuss the homogeneity of the individual smallholder clusters as well as the heterogeneity between the clusters and what implications this may carry for value chain strategy development.

**Keywords:** Cluster analysis, smallholders, targeting, value chain development

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## Performances of Private Rice Specialisation Companies in Myanmar Rice Value Chain

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Smallholder dominated rice farming and related activities play a vital role in Myanmar's economy in terms of cultivated land areas, income and employment opportunities for millions of rural households, and production and export values. In order to overcome the barriers of rice sector development such as usage of impure seed, inadequate quantity and insufficient quality of agro-chemicals, lack of sufficient credit and improved technologies as well as underdeveloped infrastructures, Myanmar government had given attractive policy such as giving priority of export licenses to private rice specialisation companies. Thus, since 2008, private rice specialisation companies have been actively involved along Myanmar rice value chain by launching resource providing contract systems in major rice growing areas of Myanmar. However, since 2011–2012, their activities have been gradually declined following changes in the incentive policy as well as incomprehensive contract system and delayed repayment of contract smallholders. The decline of their activities may negatively affect the Myanmar rice value chain in some extent. Thus, this study aimed to examine the performances of private rice specialisation companies from two major rice growing areas: Ayeyarwaddy and Bago regions during 2014–2015. Quantitative value chain approach was applied in comparison of financial performances of different rice value chain stakeholders (paddy producers, millers, local and central wholesalers, retailers and exporters) along conventional and private rice specialisation companies' value chains. The findings show that the shorter rice value chain of private rice specialisation companies via contract system shows superior in production, processing and marketing stages as compared to conventional one. In addition, performances of private rice specialisation companies indicate that the stakeholders can get the opportunities to use certified seed, better quality agro-chemicals and sufficient credit access, processing at modernised mills and producing better quality rice varieties. All this leads to a better competition position in world export rice market. The study also points out that the production and processing stages of rice value chain need new investments and improvements to have the greatest impact on growth, profitability and rice sector development.

**Keywords:** Myanmar, private rice specialisation companies, rice value chain



## **Participatory Development of Sector Strategies for Double-Purpose Cattle Value Chains in Caquetá and Guaviare, Colombia**

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The rapid globalisation of agricultural commodity markets, especially for livestock products, implies compliance with new requirements in terms of health, food safety, traceability and sustainability. In order to increase livestock sector competitiveness and to achieve access to such markets, coordinated efforts among all actors of a value chain are essential, especially when it comes to the development of joint strategies and initiatives. However, in Colombia's livestock sector, the efforts towards a market vision are often hampered by ineffective policies, disarticulation, low associativity, lack of enforcement of existing regulations and laws, and inequality in the distribution of profits among actors, resulting in limited market access and high degrees of informality.

The objective of this study is to develop sustainable sector strategies for the double-purpose cattle value chains in the Caquetá and Guaviare Departments of Colombia – in a participatory way with all involved direct and indirect value chain actors, following a two-step process. Step one comprised a basic value chain analysis through consulting primary (e.g. expert interviews) and secondary sources. Step two consists of multi-actor workshops (two per department) with the relevant value chain actors (LINK 2.0 methodology), where results from step one were shared, discussed and validated (workshop one) and a joint vision and sector strategy developed (workshop two). The value chain analysis took place early 2017, the first round of multi-actor workshops was finished April 2017 and the second round will be finished by June 2017.

As results we expect to obtain a) a profound value chain analysis, where all relevant bottlenecks for a sustainable development have been identified and later on prioritised by the actors, b) a joint vision for the value chain based on currently unmet market opportunities, and c) strategies and actions agreed among the actors for reaching sustainable value chain development. The results will be of high importance for the involved actors, as they serve as guidance on how to improve the value chains. For national and regional decision makers, the results might serve as valuable input for setting priorities (e.g., where to invest or where to prioritise for further research).

**Keywords:** Double-purpose cattle, multi-stakeholder platforms, sustainability, value chain

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## **Analysis of Pulses Industry Value Chain in Bago and Mon State, Myanmar**

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Agriculture sector in Myanmar has a fundamental role in promoting inclusive growth and poverty reduction. Pulses production has grown more rapidly than any other crop since liberalisation in 1988. The competitive structure and liberalised market of pulses has resulted in more profitable value chain engagement for farmers and other market actors along the pulses value chain, even more than for other crops. Myanmar produces over 20 varieties of beans and pulses and many of these varieties are export-only commodities. Pulses are one of the most profitable crops to farmers in terms of comparative advantage. This study aims to gain insight into pulses value chain development options and the market environment in the Bago Region and Mon State of Myanmar, with special consideration given to gender and environment dynamics. The study applied the value chain approach in identifying linkages between farmer groups, commercial buyers and private service providers in order to increase profitability throughout the industry. Primary data collection related to key actors along pulses value chains were carried out by personal interview and key informant interview methods at village cluster and township level. The pulses value chain starts from input suppliers to market intermediaries, local consumer to export market in India. Pulses processing usually involve two steps. Primary processing consists of receiving, cleaning and quality sorting of seeds. Secondary processing consists of preparing seeds for consumer use and can include dry packing, canning and the making of soup mixes, powder and flour. However, in study areas, secondary processing is minimal with the processing sequences ending at dry packing. Many of these pulses are sent in their raw state to the traders. If Myanmar can focus on producing more value added beans and pulses, improving farmers' conditions through financial and technical assistance and garnering more private and public sector research and development (R&D), the industry can continue to grow.

**Keywords:** Constraints, Myanmar, pulses, value chain

## **Multi-Stakeholder Platforms for Value Chain Upgrading. The Case of Cocoa in the Colombian Amazon**

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Colombia is currently undergoing a historic process that requires reshaping the country's agricultural and environmental policy. On the one hand, Colombia is implementing a post conflict agenda after concluding peace negotiations with the FARC guerrilla. The agreement includes important agricultural reforms which are expected to have major social and environmental impacts across the country, especially in the regions previously controlled by the FARC. Simultaneously and in connection, the Colombian northern Amazon has been experiencing greater rates of deforestation. As an attempt to align governmental, private and international cooperation efforts for addressing these issues integrally, the Colombian Ministry of Environment and Sustainable Development (MADS), the Ministry of Agriculture and Rural Development (MADR), various private and public research institutes, the country's public rural credit institute (FINAGRO), with support from international cooperation, have designed a strategy called Vision Amazonía (VA). One of VA five components recognises the role of the agricultural sector as both a driver of deforestation and at the same time, as an alternative to initiate a green growth economic pathway. One of the strategies to mitigate deforestation is to support four agricultural value chains (VCs) committed to zero deforestation goals.

The cocoa VC has been among the four prioritised VCs given its reforestation potential, its suitability to local soil and climatic conditions, niche market potential and the current presence of producer organisations and development projects in the region. In the period between January and June 2017, the International Center of Tropical Agriculture (CIAT) has been facilitating the consolidation of multi-stakeholder platforms for redesigning the sector's VC upgrading strategy, including zero deforestation and market differentiation goals in the departments of Guaviare and Caquetá, by using a participatory process that involves key stakeholders along the entire VC. This study aims at documenting the experience by providing an overview of the approaches and methodologies used, and by presenting the outcomes, strategies and action plans developed during the process. The study will also provide a critical review of the tools employed, achievements, challenges and lessons learned that will inform policy makers and implementing organisations to better design participatory zero deforestation VC development interventions.

**Keywords:** Agroforestry, cocoa, LINK methodology, multi-stakeholder platforms, value chain analysis

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## Do Palm Oil Sustainability Certifications Deliver their Promises? A Review

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Oil palm cultivation has been spreading massively in South East Asia, Central and West Africa, and Central America. Being high-yielding crops, they provide farmers with good profit margins and are attractive for the industry as the cheap palm oil can be used for a large diversity of products, e.g. cooking oil, personal care and cleaning products or biofuels. The downsides of production are negative effects on the environment and society such as deforestation, habitat destruction, green-house gas emissions, and human right offenses. Concerns about negative impacts on local food security are also raised. Therefore, palm oil sustainability certifications were introduced in the last decade and aim to address these challenges. Since the oil palm sector continues to be under critique, this research reviews scientific and grey literature for the sustainability challenges in the oil palm production and how far they are successfully addressed by certification systems. It focuses specifically on the impacts of the sustainability certifications on the environment, human rights and food security.

The comprehensive literature review shows that effects of oil palm production vary according to the socio-economic and agro-ecologic production systems across continents, i.e. in West Africa more positive sustainability effects are found while in South East Asia the opposite is the case. Trade-offs between the different sustainability dimensions clearly exist: Socio-economic benefits, especially for smallholders, stand often against peat land conversion, deforestation and habitat destruction. Sustainability certifications can only address the identified challenges to a certain degree. For example, food security aspects are insufficiently covered by the certifications. Despite certification, deforestation and human right offenses continue and inherent problems related to market demand and controls exist. Additionally, only a small share of production is covered by voluntary sustainability standards while governmental standards, such as in Indonesia, are not sufficiently enforced. To improve the sustainability of oil palm production, more engagement is needed at producer country level, for example law enforcements, major palm oil consumers (like China) need to request also sustainability criteria and multinationals need to offer higher price premiums for compliance with higher sustainability standards, supported by a consumer demand.

**Keywords:** Certification, food security, human rights, oil palm, sustainability

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## Enhancing Skill-Sharing within Multi-Stakeholder Processes: An Example from the Small-Scale Dairy Chain in Kenya

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The small-scale dairy value chain, comprised of smallholder dairy farmers, mobile traders and retailers in milk bars, plays a major role in Kenya's food security. As much as 80 % of the country's milk is marketed through this chain, and it is sold at about half of the price of milk sold in the supermarket. Yet members of the small-scale dairy value chain face several challenges, such as limited coordination, high seasonal fluctuations of milk supply, and the need for context-specific information. To overcome these challenges, this study analyses skill-sharing between the different actors of the small-scale dairy value chain to create diverse benefits both from the learning process and from improved practices.

Data was collected in Nakuru, Kenya from November 2016 until February 2017 through participatory methods, including small-scale dairy multi-stakeholder platform meetings, peer-to-peer exchanges, group trainings, and narrative interviews. All activities were conducted with between 13 – 16 people.

Coding this qualitative data offers results about the information needs of the stakeholders, types of information exchange and what stakeholders learn from the process. To create value in low-external input systems, the stakeholders needed different types of information, such as botanical knowledge for diverse cropping systems, an understanding of the qualities of different affordable insulation materials for making yoghurt, etc. Additionally the stakeholders augmented their critical thinking skills through information exchange in peer-to-peer visits. Both the benefits of the learning process and the benefits of the activity of focus are presented.

The study shows that the collaborative learning process was mutually beneficial for the stakeholders, despite their different perspectives, interests and information needs. This research further confirms that collaborative learning processes are particularly important for actors working in low-external input systems that require highly context-specific information and practices.

**Keywords:** Multi-stakeholder platform, skill-sharing, small-scale dairy, value chain improvement

## Collaborative Product Development to Enhance Local Food Security and Livelihoods in Eastern Africa

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Processing of primary agricultural and forestry food products by rural producers or community-based enterprises can considerably contribute to local food security, employment, alternative household income and improved livelihoods. The development and launching of new products by firms has key influence in achieving such objectives since it contributes to continuous business success and growth of the involved companies. The development of new, marketable products has primarily been approached from the perspective of the companies involved in production and sale of such products. However, it is increasingly recognised that successful product innovations is the outcome of a collective effort rather than the achievement of a single person or firm. Furthermore, it has been demonstrated that collaboration and stakeholder involvement in the new product development process has positive effects on its market success.

Such considerations are currently being addressed and put into practice within the BAOFOOD project. The project aims to promote the domestication, production, market development, processing and consumption of baobab for the improvement of food security, nutrition and rural livelihoods in Kenya and the Sudan. The project's ultimate goal is to establish a community-based processing unit to produce and supply highly nutritious baobab products for home consumption and local and regional markets.

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Local baobab producers and processors, often characterised by limited resources and expertise for product and business development, are given the opportunity to collaborate with a variety of stakeholders including members across the baobab value chain, research institutions, or regulatory bodies as well as benefit from the project and the insights it generates in customer needs and expectations, technology development and optimisation, or value chain setups. The development of marketable products requires local producers and processors to understand demand and consumer preferences at various markets, and mobilise the technical and economic expertise required to meet these demands in a competitive environment. This approach gives the opportunity to not only contribute to food security and improved livelihood objectives but also to help build local entrepreneurial skills and verify the applicability of this more unconventional product development pathway. The paper presents the approach in more detail as applied by the BAOFOOD project.

**Keywords:** Baobab (*Adansonia digitata* L.), food security, product development

## The Impact of Management Practices on Pre-Mortem Meat Quality along the Colombian Cattle Value Chain

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Cattle production is the most important activity in the Colombian rural sector. However, the Colombian cattle value chains show high levels of disarticulation at all stages, which limit the involved actor in achieving substantial increases in competitiveness and sustainability. On the other hand, this also leads to low levels of compliance with current environmental, animal welfare or food safety regulations resulting in limited access to more formal national and international markets.

With the aim of identifying critical points in terms of pre-mortem management practices, this study examined the degrees of compliance with national norms among the cattle value chain actors at pre-mortem stages (primary production, animal transport and animal trading). The study was carried out in 2016 and 2017 and the methodology followed a three-stage process: 1) by consulting the Resolution 20148 (2016) issued by the Colombian Agriculture and Livestock Institute (ICA), a checklist was developed and applied with small and medium-scale cattle producers in the Colombian Cauca Department, that allowed measuring the degree of compliance with the norm. 2) Through interviews with animal transporters and traders, the different animal marketing channels were identified and the transporting and trading practices were evaluated regarding their compliance with national regulations. 3) A profound literature review was conducted in order to identify the magnitude of negative impacts of different management practices on meat quality and to develop strategies for improvement.

First results show that practices leading to compliance with animal welfare regulations are the ones being less regarded by the actors (5 % compliance level), whereas practices leading to compliance with animal health and biosafety regulations are the ones of most importance to the actors (<23 % compliance level). The results will help to identify gaps in terms of the regulatory framework and its application at pre-mortem value chain stages and be of high value for the involved value chain actors and decision makers in order to develop the value chain and achieving access to more formal national and international markets.

**Keywords:** Animal trading, animal transport, cattle production, checklist, value chain

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## ***Post mortem* Management and Microbiological Presence as Quality Factors along the Beef Value Chain in Colombia**

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The production of high quality food for formal national and international markets is among the principal goals for the development of the Colombian agricultural sector. In such markets, the final consumer expects to buy products of high quality in terms of both taste and food safety. For being able to access those markets, it is fundamental that the value chain actors follow strict food safety protocols and that effective and efficient control mechanisms are in place. Yet little is known in that aspect in most of Colombia's beef value chains.

With the goal of determining the food safety along the beef value chain in Colombia, this study assesses the beef management practices and contamination levels with microorganisms at post-mortem value chain stages in the Colombian Cauca Department (Popayán, Patía and Mercaderes municipalities). The assessment follows the Good Manufacturing Practices concept (GMP), including an evaluation of contamination levels with *Escherichia coli*, Coliform bacteria and *Pseudomonas*.

Data was obtained in a two-stage process between 2016 and 2017: The first stage was the application of a checklist for different types of meat sellers (n=63), which is based on the current Colombian food safety regulations. In the second stage, microbiological tests (3M@ protocol; n=27) were carried out to determine and quantify the presence of *E. coli*, Coliform bacteria and *Pseudomonas* in the final product.

The results of the checklist show low levels of compliance with current food safety regulations (<60%) among the meat sellers. Microbiological tests reveal high Coliform bacteria contamination (100%) for all meat selling establishments in Popayán and also contamination with *E. coli* and *Pseudomonas* (>90%) in small and larger establishments. Microbiological tests were negative for the Mercaderes municipality showing the positive effects of applying GMP and a cold chain for quality assurance. The results helped to identify critical points in terms of food safety along the value chain and will facilitate the development of adequate food safety measures, protocols and control mechanisms by the value chain actors and the corresponding authorities, as first step towards the development of a safer beef value chain and compliance with national and international standards.

**Keywords:** Coliform bacteria, *Escherichia coli*, food safety, *Pseudomonas*

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## Strengthening the Linkages between Farmer Producer and Manufacturer in the Coffee Value Chain of Daklak, Vietnam

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The international coffee price volatility and pressurisation of multinational coffee corporations on the local exporters/manufacturers demand a better linkage among production, processing, and marketing in the Daklak coffee sector. Beside the commitment, responsibilities, and share of risk, the development of trust between the company and the farmer depends on the continuous flow of significant economic gain. This study attempted to analyse the relationship between coffee farmer producers and manufacturers as well as the problems and constraints that impede these stakeholders benefit from the system. The Pearson's chi-square test was employed to assess the statistical significance of farmer responses across the study sites. The results revealed that coffee farmer producers and manufacturers are vertically linked through contracting, providing, supporting, collaborating, and mostly buying and selling transaction. The relations are typically based on a written contract, which defines quantity procured, supply of input, extension advice, and technical support. Contracts mostly are seasonal and carried out by the manufacturer with each farmer household who commit the quantity they can supply in specific farming areas. Contract also terms in particular coordination activities between both parties to guarantee the production outcome, purchasing price, time delivery, payment method, and both parties' responsibility for risk in production and market price fluctuation. The capital shortage, water scarcity, small scale production, lack of collective action in quality control, and obsolete local infrastructure have long been the problems and crucial challenges for coffee farmer in order to secure their participation in this sector. In fact, the government's discontinued intervention in the last decade has left the Daklak coffee industry now operating primarily through private sector.

**Keywords:** Contract farming, linkage, value chain

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## Limiting Factors in the Development of Vegetable Value Chains in Southeastern Madagascar

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Food insecurity prevails in many parts of Madagascar. The Atsimo-Atsinanana Region, located in the Southeast of the country, ranks first with a lean period of 6 to 7 months compared to a national average of 5 months and a prevalence rate of 64% in 2012. The population of this area shows an enormous deficiency in micronutrients, partly due to an infrequent, low-level and low-diversity consumption of vegetables.. Vegetable crops, which are grown on very restricted surfaces, are also weakly developed. However, this region with its hot and humid climate almost all the year and its characteristic terroirs presents agro-climatic conditions favourable to vegetable crops. In addition, almost all the vegetables sold in the urban markets of the region come from the Malagasy highlands. The purpose of this paper is to explain why local producers do not address the needs of urban consumers for vegetables.

The value chain approach is considered the most appropriate way to conduct this study by highlighting the bottlenecks faced by the various actors, including producers, traders, urban consumers, Nutritional aspect. The approach adopted focuses on in-depth surveys of about 100 producers, about thirty traders and some 60 urban consumers. The results show that local growers mainly grow leafy vegetables (petsai, cabbage sprouts) and fruit vegetables (African eggplant, eggplant), which are mainly intended for self-consumption. These are short-cycle crops but also do not require a lot of inputs or interviews. Thus, the current perceptions of producers regarding vegetables limit the diversification of vegetable crops. The results also show that the preferences of urban consumers focus mainly on vegetables of better nutritional quality (carrot, potato, tomato, green bean) compared to those of producers. Divergent perceptions of producers and consumers limit the development of vegetable value chains.

**Keywords:** Actors, producers, traders, urban consumers, value chain, vegetables

# Risk and awareness

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## Invited Paper

- LIZ WATSON:  
**Future Agriculture: Development Visions and Socio-Ecological Transformations in Africa** 478

## Oral Presentations

- YAREMI KARINA CRUZ RIVERA:  
**Mountain Communities' Perception of Climate Change Adaptation, Disaster Risk Reduction and Ecosystem-Based Solutions in the Chicon Watershed, Peru** 479

- MULUKEN ELIAS ADAMSEGED, AYMEN FRIJA, ANDREAS THIEL:  
**Dynamics of Rural Livelihoods and Rainfall Variability in Northern Ethiopia** 480

- LYDIA AFRIYIE, ASTRID ZABEL, LAWRENCE DAMNYAG:  
**Index-Based Insurance for Cocoa Production in Ghana: Just a Mirage?** 481

- NGA PHAM THI THANH, ARCHANA RAGHAVAN SATHYAN, MATTHIAS GARSCHAGEN, JAKOB RHYNER:  
**Assessing Household Vulnerability to Flash Floods and Landslides: Key Insights from Vietnam** 482

## Posters

- GETACHEW LEGESE FEYE, TILL STELLMACHER, HAILE-MARIAM TEKLEWOLD BELAYNEH, KRISTOF VAN ASSCHE, GIRMA KELBORO:  
**Local Community's Perception, Assessment and Management of Food Insecurity Risks: The Case of Family Farming Households in South Western Ethiopia** 483

- BISRAT HAILE GEBREKIDAN, THOMAS HECKELEI, SEBASTIAN RASCH:  
**Farmers Intensification Decisions under Fragile and Unpredictable Environment in Kilombero Valley Floodplain: A Bayesian Belief Network Approach** 484

- AKARY MIN, HARALD STERLY, MATHIAS BECKER, PATRICK SAKDAPOLRAK:  
**Farmers' Perception and Adaption to Climate Change in the Central Dry Zone of Myanmar** 485
- BAMLAKU ALAMIREW ALEMU, TIM K. LOOS, HABTAMU DEMILEW YISMAW:  
**Agroforestry-Food Security Nexus: Future Potentials of Bamboo to Food Security Enhancement in Ethiopia** 486
- AIMÉ HERI-KAZI BISIMWA, CHARLES BIELDERS:  
**Farmer's Perceptions of Land Degradation in South Kivu, Eastern DR Congo** 487
- TILL LUDWIG:  
**Impact of Economic Preferences on Food and Nutrition Security in Risk-Prone, Rural Environments** 488
- EMILY MUTOTA, STEPHANIE DOMPTAIL:  
**Using of Photovoice to Elicit Socio-Cultural Values of Eco-system Services in a Rural Community, Namibia** 489
- GONZALO PRADILLA, TOMÁS E. LEÓN-SICARD:  
**Environmental Analysis of Peasant Resilience Practices to Climate Change and Variability in Ecological Farms on the Cundiboyacense High Plains – Colombia** 490
- ALEXANDER MEWES:  
**Community Characteristics and Risk Perception in Agriculture: A Case Study in Rural Northern Ghana** 491
- MINH TU NGUYEN, ZITA SEBESVARI, FABRICE RENAUD:  
**Subjective Measurement of Resilience of Agricultural Systems to Increased Salinity Intrusion in Vietnam** 492
- LEONIE KREIPE, EVA WIENERS, EVA SCHLECHT:  
**Climatic Changes in the Mid-Hills of Nepal: A Study on Small-holder Farmers' Perception and Reactions** 493
- TAISSER H. H. DEAFALLA, ELMAR CSAPLOVICS, MUSTAFA MAHMOUD EL ABBAS, MOHAMED EL NOUR TAHA:  
**Analysing the Effects of Conflicts on Agricultural Production, Case of Nuba Mountains Region** 494
- DONI YUSRI, HEIKO FAUST:  
**Perspectives of Stakeholders Towards the Development of Eco-tourism as Collective Actions of Sustainable Collaborative Management in Kerinci Seblat National Park, Sumatra, Indonesia** 495

ANYWAY KATANHA, DANNY SIMATELE: <b>Natural Hazard Mitigation Strategies Review: Actor Network Theory and the Eco-Based Approach Understanding in Zimbabwe</b>	496
CHRISTIAN BUNN, MARTIN NOPONEN, MUSTAPHA DALAA, LAURENCE JASSOGNE, MARK LUNDY: <b>Forward Looking Prioritisation of Farmer Innovation for Climate Change Adaptation in Cocoa Production in Ghana</b>	497

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## Future Agriculture: Development Visions and Socio-Ecological Transformations in Africa

LIZ WATSON

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African rural environments are currently characterised as places of crisis and opportunity. The dryland regions of East Africa, for example, are portrayed as areas that are particularly vulnerable to the contemporary ‘grand challenges’ of population growth, climate change, food insecurity and political instability. At the same time, they are also seen as new lands of opportunity: as poorly developed areas with unexploited resources, investment there is thought to be able to reap good returns, and to potentially drive the growth of ‘rising’ national economies. This context, together with other factors, has led to a flurry of new development visions, plans, policies and initiatives. Together, these activities can usefully be described as forms of ‘future-making’ (Appadurai 2013), that employ particular kinds of ‘socio-technical imaginaries’ (Jasanoff and Kim 2015). Historically, researchers have not paid much attention to these imaginaries, but they play a huge role in social, environmental and political outcomes. Appadurai (2013) distinguishes between two kinds of future-making: the aspirational, that is more ‘open’, and connected to ‘informed, creative and critical citizenship’; and the ‘anticipatory’, a more reductive, probability-based approach. Empirical research suggests that in dryland East Africa at least, the perceived moment of crisis and opportunity has brought with it more anticipatory forms of future-making that embrace urgent and large-scale solutions and the involvement of supposedly more effective international management consultancy companies. They have tended to employ ‘socio-technical imaginaries’ that occlude local visions of the future and cast existing agricultural practices as non-existent, inadequate or environmentally degrading. If successful, these anticipatory forms of decision-making will result in a biocultural shift – from relations to nature that are socially embedded, socially managed and locally negotiated, to ones that are increasingly commoditized and enclosed. The process is complex: the future is not a choice between experts vs citizens, modern vs customary/traditional, local vs global, private ownership vs the commons, or subsistence vs markets. What is clear is that rural development and natural resource management is at the centre of this dynamic future-making process, and that it is possible for that future-making to be more aspirational, based on socio-technical imaginaries that are more empirically grounded, created and owned by all.

**Keywords:** Agricultural transformation

## **Mountain Communities' Perception of Climate Change Adaptation, Disaster Risk Reduction and Ecosystem-Based Solutions in the Chicon Watershed, Peru**

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Located in the Urubamba mountain range, the Chicon glacier is one of the third highest tropical glaciers of Peru and is the source of water of the Chicon Watershed. Moreover, from this watershed four communities obtain water for human consumption and agriculture, which is their main economic activity. In the last years glacier retreat is evident in the area and threatens the livelihoods of the people.

The general objective of this research is to analyse the perception of people living in this watershed to climate change, disaster risk and ecosystem-based solutions. The specific objectives are to identify natural hazards and climate change effects in the community, to recognise potential ecosystem services suitable for ecosystem-based adaptation (EbA) and ecosystem-based disaster risk reduction (Eco-DRR), and to assess to which climate change effects and disasters the communities are vulnerable based on their own perception. The methodological steps are based on literature review, expert interviews, questionnaires at community level, workshop and field observations.

The results show that people perceive changes in the climate such as increase in temperature, less precipitation and shifts in rainy and dry season. The climate-related disasters that were identified are glacial lake outburst floods (GLOF), droughts, frosts and hailstorms. However, GLOF are not frequent in the area and drought is the hazard considered to become more frequent. Additionally, pests were identified as biological hazards. Several ecosystems services can be obtained for EbA and Eco-DRR from forests, especially if native trees such as Qiwiña (*Polylepis*), Chachacoma (*Escallonia resinosa*) and Aliso (*Alnus jorullensis*) are exploited.

Finally, the tested hypothesis was rejected as people in the study area are well aware of climate change impacts, although they only partially understand causes and effects. However, they recognise and exploit ecosystem services provided by the forest. Therefore, local population started to implement ecosystem-based solutions in the watershed with support of external institutions.

**Keywords:** Chicon watershed, climate change, disaster risk reduction, ecosystem-based solutions, perception of communities

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## Dynamics of Rural Livelihoods and Rainfall Variability in Northern Ethiopia

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This study examines the association of livelihood dynamics of rural households in Ethiopia with rainfall conditions and socio-economic characteristics, using a 15-year panel data set. The data is collected in two communities in Tigray and Amhara regions. We employed fixed and random-effect conditional logit models to explain household decision-making processes regarding livelihood strategies. Our finding shows that participation of rural households in non-farm livelihoods has been increasing over the years but with great fluctuations. We also found that rainfall conditions during the main rainy season negatively and significantly affects household decisions to pursue non-farm livelihoods. The motivation of farm households to diversify into non-farm livelihoods is mainly driven by low-performance farming outcomes as well as demographic characteristics (specifically adult household size, human capital and education) and degree of access to financial schemes. These findings suggest policy implications for increasing access to financial schemes and improving household-member skills through vocational training and education to enable them to engage in high-return and profitable non-farm livelihoods.

**Keywords:** Business activities, household, livelihood, non-farm activities, rainfall, wage employment

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## **Index-Based Insurance for Cocoa Production in Ghana: Just a Mirage?**

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Index-based rainfall insurance is a financial adaptation option that pays out benefits based on a predetermined index e.g. rainfall level. It is a measure that has the potential to improve cocoa farmers' resilience and enhance their adaptability to climate change induced risks. However, the complex nature of the cocoa sector and the organisational structure of Ghanaian farmers create uncertainty about the adoption and successful implementation of index insurance. This paper presents results of a study on factors impacting farmers' willingness to pay for index insurance as well as organisational and institutional factors that can influence its demand and adoption in Ghana. Primary data were collected through structured surveys with 313 households in 20 communities in Bia East and Dormaa West districts. In addition, five insurance companies were interviewed to determine their interest in and potential challenges for the establishment of a market for index insurance products for farmers. Key informant interviews were conducted with representatives of the Ghana Cocoa Board to determine the factors that can affect adoption of index insurance.

Econometric analysis of the data reveals that indeed the vast majority of cocoa farmers are willing to pay the equivalent of 10 % of the value of a 62 kg of bag of cocoa as insurance premium. Insurance companies will be willing to provide index insurance packages to cocoa farmers provided there is time series yield and meteorological data available to help them structure the premium. Insurance companies, however, are concerned about farmers' level of education and organisation and how index insurance can be sold to them. The main policy recommendation based on these findings is to advance the concept of index-based insurance by training the cocoa extension service division with support of the Ghana Cocoa Board to educate farmers on index insurance. However, with no clear structures and resources allocated for adoption and implementation for index insurance, its future remains unclear.

**Keywords:** Cocoa farmers, Ghana, index-insurance, willingness-to-pay

## Assessing Household Vulnerability to Flash Floods and Landslides: Key Insights from Vietnam

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Vietnam is one of the most natural hazard-prone countries in East Asia. Every year it loses 1–1.5 percent of GDP due to natural disasters which hinders the socio-economic development of the country. Seventy percent of the population is concentrated in the floodplains and coastal areas relying on natural resources for subsistence especially smallholder agriculture. Flash floods and landslides are recurring disasters which heavily affect the country in terms of land area impacted, population affected and economic loss. In addition to this, climate change accelerates the negative impacts on the livelihood of these poor rural households.

Against this background, this paper presents the Livelihood Vulnerability Index (LVI), a composite index, to estimate the vulnerability level of smallholder farmers to these hazards. As a case study, we selected Yen Bai province, one of the poorest provinces in the Northern Mountainous Region of Vietnam with a high proportion of ethnic minorities. This province is frequently affected by flash floods and landslides. Based on collected data from 406 households in three communes: An Binh, An Thinh and Dai Son, the LVI is calculated under seven major components namely socio-demographic, livelihood strategies, social networks, health, food, water, and hazard impacts. The results show that Dai Son commune has the highest LVI and is the most vulnerable due to its high vulnerability values in socio-demographic and water security components. On the other hand, An Thinh is considered as the least vulnerable because of better social networks, health standard, socio-demographic factors and water security. Most of the agricultural lands of the households are damaged by flash floods and landslides thus leading to insufficient on-farm food. Therefore, 'food' is the most vulnerable major component in the three communes. These findings can contribute to the identification and prioritisation of measures to ensure better food and water accessibility through production system enhancement and natural resource management strategies. The LVI is replicable for assessing the vulnerability of small holder farmers in other hazard-prone areas.

**Keywords:** Flash floods, hazard-prone areas, landslides, livelihood vulnerability index, Vietnam, Yen Bai province

## Local Community's Perception, Assessment and Management of Food Insecurity Risks: The Case of Family Farming Households in South Western Ethiopia

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Family farmers in Ethiopia constitute over 81 % of the total population of the country and account for more than 95 % of the total agricultural production. However, these farmers are operating under continuous threats of complex sets of risks. The purpose of this study was to assess local community's risk perceptions, assessment and management practices to mitigate food insecurity risks. We used a mixed methods approach comprising qualitative and random quantitative survey data from Jimma and Bako areas in Oromia region of southwestern Ethiopia. Results indicate that climate-related variables and institutions influencing agricultural inputs, outputs and food prices were important sources of household food insecurity risks. Noteworthy, 90% of farmers in the sample perceived that late onset of rain was the major source of risk. Similarly, 55 % reported that early cessation of rainfall is the major sources of risk of food insecurity. About half of the sample indicated that extended drought was a major source of risk. In addition, 70% reported that they experienced effects of late onset of rain while 30 % and the full sample experienced early cessation of rainfall and drought in the last five years, respectively. Farmers assessed drought as a difficult to predict and avoid source of risk with the highest negative impact on crop productivity. Market and institutional variables were additional sources of risk. Results show that 78 % and 98 % of farmers, respectively, perceived that large decreases in maize prices and large increases in input prices were important sources of food insecurity. High input costs and low grain prices have been important disincentives to increasing grain production in Ethiopia for over the last six decades. Households and the local community at large are using different risk management strategies to protect themselves from food insecurity. These strategies range from risk coping strategies such as reduction of consumption to adaptation strategies such as use of short season and early maturing crop varieties and development of suitable crop agronomic practices in response to changing sources of food insecurity. Promoting such coping and adaptation strategies would be essential to build sustainable solutions to food insecurity.

**Keywords:** Local community, risk assessment, risk management, risk perception

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## Farmers Intensification Decisions under Fragile and Unpredictable Environment in Kilombero Valley Floodplain: A Bayesian Belief Network Approach

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Like Most of the countries in sub-Saharan Africa, Tanzania have continued facing the challenges of feeding their growing population coupled with increasingly degrading environment and uncertainties resulting from climate change. Based on this revelation, the government of Tanzania and different international and local NGOs are embarked on a strategy that increase in food production and poverty reduction should come from development of the agricultural sector through “sustainable” agricultural intensification in selected targeted clusters of potential agriculture hotspots across the country. The Kilombero Floodplain (KVFP) is endowed with a productive natural resource base, fertile land, reliable water availability and extensive pastures to small holder farmers in Kilombero and Ulanga districts. However, the supply of productive land is increasingly constrained by population pressure, competition from commercial ventures and institutional land tenure restrictions. These forces farmers who intent to increase production quantities to adopt different agricultural intensification strategies. A range of intensification pathways including use of improved/hybrid seed variety, increase frequency of cropping, small-scale irrigation, and agro-chemical input use are identified in the area. Aimed at identifying appropriate pathways to intensification strategies which overlaps with their livelihood strategies by farmers, this study dissects an important question of which strategies do the farmers uptake and how are these decisions made. By combining statistical tools from machine learning (multivariate cluster analysis and Decision tree algorithm) and probabilistic graphical models (Bayesian Belief Network) under uncertainty, we empirically examined the decision making process of farmers in KVFP. The preliminary result shows the relative importance of different external factors and regional settings (biophysical characteristics of their farm plot, access to input and output market, credit access, and off-farm livelihood opportunity) and internal characteristics of the farmer (age household size, farmer type, household commercialisation index, capital endowment) were found to be the main factors that farmers consider in their choice intensification strategies. In addition, farming practices, intensification strategies in particular, in the floodplain are associated with trade-off between increased food productions and sustaining the ecosystem services provided by the floodplain.

**Keywords:** Agriculture, Bayesian Belief Network, floodplain, food productions, intensification, Tanzania

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## Farmers' Perception and Adaption to Climate Change in the Central Dry Zone of Myanmar

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The Central Dry Zone covers about 13% of Myanmar and is home to nearly a third of the total population of 52 million. The majority of households depend on agriculture-based income (83%). Besides low profitability, poor diversification, and high reliance on credit, these agricultural households are subject to additional stress by soil degradation, erratic rainfall patterns and extreme temperatures, and commodity price fluctuations. Particularly the climate change phenomena have become recently a major constraining factor for agricultural production in the Dry Zone. In this study we explore how farmers perceive agricultural problems in relation to climate change, and which strategies they apply to cope with and adapt agricultural practices to climate change based on traditional knowledge. Based on household surveys, participatory rural appraisals (PRA) and key-informant interviews it can be concluded that most farmers recognise climate change as a key constraint as they perceive their agricultural production being severely impacted, particularly by erratic rainfall. In response to increasingly frequent pre-monsoon droughts, some farmers have actually abandoned during the past 15 years cultivating rice as the main subsistence and market-crop, but also the cultivation of pre-monsoon crops such as sesame. Most farmers have traditionally been dealing with climatic risks by providing supplementary irrigation, e.g. by establishing tube wells, by cultivating short-cycled cash crop instead of rice, and by substituting annual crops by fruit orchards. In the recent past, their adaptation repertoire has been complemented by institutional assistance from government organisations, namely in the form of improved weather forecast, training activities, and the provision of adapted seeds. In addition, there has been improved access for some farmers to communication infrastructure or improved agricultural technologies. These differential affect adaptation to climate change and changes in cropping patterns and agronomic practices. We will present preliminary findings from the ongoing research project on how traditional adaptation strategies blend and interact with external "modern" strategies to adapt to climatic change processes in the dry zone of Myanmar.

**Keywords:** Drought, information technology, institutional assistance, *Oryza sativa*

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## Agroforestry-Food Security Nexus: Future Potentials of Bamboo to Food Security Enhancement in Ethiopia

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Ethiopian rural households make significant part of their livelihood from natural resources in general and from forest produces in particular. Bamboo is one of the most important forest resources in the country, which is estimated to be around one million hectares, of which 850,000 ha are lowland and 350,000 ha are highland bamboo varieties. This is the largest bamboo area in Africa. Apart from serving as source of energy, fodder and construction, bamboo can serve as an input for small and micro-enterprises (SMEs) via forward and backward linkages. Its production is a major part of farming system and source of livelihood for rural people. Notwithstanding such higher potential for both livelihoods enhancement and environmental sustainability, the sector has been overlooked for a long time. Being cognizant of the benefits of bamboo, attention has been given to the sector since recently. This research was conducted with the major objective of providing an insight into the current status and future potentials of the bamboo sector in Ethiopia in order to enhance sustainable livelihoods. The research mainly used primary data for its analysis. The sample for this research was drawn from the two-major bamboo growing national regional states in Ethiopia, Amhara and Benishangul Gumuz. A total of 486 sample households were randomly selected. Both quantitative and qualitative data were collected. Survey questionnaire was the main tool to collect the quantitative data while the qualitative data were collected using focus group discussions, key informant interviews and case story narrations. Ordered response models and principal component analysis were applied to analyse the food security status of smallholder farmers captured by their food consumption score, dietary diversity scale, and coping strategy index. Results suggest that bamboo has untapped potential to ensure food security – especially to poor rural smallholder farm households. To tap into the full potential of bamboo, a collective action of the government, NGOs and other stakeholders is required to create awareness among smallholder farm households and artisans about the diverse benefits of bamboo, improved methods of growing and extracting its culms and adoption of modern and up to date technologies.

**Keywords:** Agro-forestry, bamboo biomass, Ethiopia, future agriculture

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## Farmer's Perceptions of Land Degradation in South Kivu, Eastern DR Congo

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The Kivu dorsal in South Kivu is characterised by variable rainfall conditions, and a diversity of soils and cropping systems. Furthermore, socioeconomic contexts vary widely both in terms of population density and their access to land, agricultural extension services, road infrastructures and markets. These factors are expected to affect the degree of pressure on soil resources. This study aimed at assessing how the diversity in biophysical and socioeconomic contexts affect crops choice, and farming practices in South-Kivu and the resulting status of soil degradation as perceived by farmers. Household and community surveys were carried out in eight watersheds from four territories dominated by smallholder farming systems in South Kivu. Survey data were assessed based on percentage frequency; descriptive statistics; factor analysis and chi-square methods. Result showed that heterogeneity was observed at different scales (territory and watershed) due to biophysical and socioeconomic contexts, and farmer's perception of the status of degradation was affected by this variability. Based on the farmers' own criteria (possessed lands, types of cattle, access to markets. . .), four types of farm were identified and described, and their important characteristics outlined. In most watersheds (more than 74%), erosion was the main cause of degradation. More than 10 crops were grown to satisfy food requirements and agricultural practices were associated depending on each site and their available means. The hierarchical ascending clustering analysis made for these three criteria (crops, practices and degradation status) has shown strong links between the topographical location and the status of degradation, the status of degradation and crops as well as the practices adopted in farmer's fields. But regarding the farming practices, differences were very small across sites. Similar trends were observed in both watersheds of each territory and were often characterised in the same way, in terms of degradation status or in terms of adopted crops. Overall, analysis of soil degradation processes was better understood after analysing socioeconomic and biophysical contexts of the concerned areas.

**Keywords:** Agricultural practices, eastern DR Congo, farming system, soil degradation, South-Kivu, watershed

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## **Impact of Economic Preferences on Food and Nutrition Security in Risk-Prone, Rural Environments**

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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 – can impact food and nutrition security of individuals, and of dependent household members. Yet, empirical evidence is scarce. Therefore, this study explores the linkages between behavioural preferences and food and nutrition security utilising a household-level survey.

The household survey is carried out in rural areas of East 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 randomized sampling technique from 85 villages. FNS indicators are obtained (e.g. FIES, MDDW, MAD, anthropometric measurements) and form a comprehensive understanding of malnutrition rates among households and individuals. 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. Additionally, socioeconomic, demographic and social aspects are surveyed. Additionally, a village-level recall questionnaire is utilised in focus group discussions.

Basic descriptive statistics hint at severe nutritional status of the households. Key informant interviews indicate qualitatively the relation of time preference and preferred food consumption and the level of altruism to the nutritional status of dependent children. Risk and time preferences seem to be dominated by risk averse behavior and short-term preference. Final results will indicate to which extent behavioural preferences impact the nutritional status focusing on women in reproductive age and on their children below 2 years of age, controlling for determinants that have been established in previous literature. The study will add to the literature by empirically assessing the influence of core concepts of behavioural economics on food and nutrition security.

**Keywords:** Economic preferences, food nutrition security, India, risk, rural areas

## Using of Photovoice to Elicit Socio-Cultural Values of Ecosystem Services in a Rural Community, Namibia

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Economic valuation of ecosystem services has been criticised as inadequate to advise decision-making, as it fails to reflect the plural socio-cultural values that people attribute to nature. Efforts are ongoing to better capture the socio-cultural values (SCV) of ecosystem services. Consequently, this study contributes to the improvement of the socio-cultural assessment and valuation of ecosystem services, using the photovoice approach. Photovoice is a participatory approach whereby members of local communities personally take photos and use them to generate narratives. In this study, this methodology is used to communicate the social and cultural reality which characterises people's relationship with nature.

The Kavango West region in Northern Namibia, until recently a subsistence economy, is undergoing changes including the intensified use of natural resource. We hypothesise that a change in SCV is related to the change in practices, and investigated the SCV in two villages near Nkurenkuru. Prior to eliciting SCVs, we examined the historical socio-cultural elements characterising the relationship between the smallholders and their ecosystem services.

The data consists of 165 photos and 170 narratives. MAXQDA, a qualitative analysis tool was applied to classify SCV, and thematic analysis was used to construct meanings of the identified SCV. Findings from 20 photovoice participants revealed multiple myths, taboos and practices related to use of river and forest ecosystems. For example, some participants photographed landscapes and told narratives about the Ekongoro, a mythical figure (or supernatural snake) which is believed to be the provider and the ruler of water and water resources, such as fishes. Ekongoro is valued but feared for its role in governing and managing water resources. This example shows that Ekongoro is a belief system that influences how people use their ecosystems.

Overall, the SCVs identified provide insight on the valuation and management of all Millennium Ecosystem Assessment (MEA) service categories. Photovoice proved excellent in eliciting deep cultural elements which explain what nature means to people. The study highlights that assessment of SCV of ecosystem services should understand and include people's cultural belief systems. This is essential in rural subsistence societies where cultural belief systems still have an influence on people's action and decisions.

**Keywords:** Ecosystem services, Kavango, photovoice, socio-cultural values, subsistence communities

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## **Environmental Analysis of Peasant Resilience Practices to Climate Change and Variability in Ecological Farms on the Cundiboyacense High Plains – Colombia**

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We studied 12 agroecological smallholder farms in the municipalities of Guasca (Cundinamarca), Paipa and Duitama (Boyacá), in order to: 1. identify potential impacts of climate variability on production, incidence of pests and diseases, and income; 2: analyse the capabilities, potentialities and limitations of each agroecosystem to mitigate, cope and adapt to climate change and variability (resilience). We evaluated and scored 58 biophysical and cultural variables and grouped these into 11 components: physical conditions; soil quality; soil, water, and crop management; main agroecological structure (MAS); and social, economic, institutional, political, and technological aspects. The methodology included the review of secondary sources and field visits, in which semi-structured interviews, participant observation and social mapping were conducted, along with a description of biophysical, soil and agricultural characteristics of each farm. The results show that all farmers have faced negative impacts associated to climate variability, being water scarcity the most common cause, followed by frost and heavy rains and flooding, with marked differences between locations. The overall resilience level rated all farms at similar levels (between 3.74 and 2.83), being slightly higher in the Guasca locality (average 3.47) compared with Paipa - Duitama (average 3.11). Agroecological management of soils and crops, addition of organic matter to the soil, rain-water harvesting, construction of reservoirs, small-scale irrigation systems and greenhouses, coupled with social organisation and productive association, proved to be the most important strategies to increase the resilience of agroecosystems, while the main barriers to their adoption and scaling up were the limited access to capital, markets, financing and technical assistance.

**Keywords:** Adaptation, agroecology, agroecosystems, climate variability, rural livelihoods, socioecological systems

## Community Characteristics and Risk Perception in Agriculture: A Case Study in Rural Northern Ghana

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Reducing risk in agriculture is the aim of many interventions in West Africa. Target groups predominantly consist of smallholder farmers threatened by the present and future impacts of climate change. Smallholder farmers in northern Ghana live in culturally and socio-economically diverse communities with similar environmental challenges. This study identifies non-environmental community characteristics related to risk perception in agriculture on the inter- and intra-community level. We want to show how risk reduction interventions such as improved seeds and sustainable planting practices affect communities and individuals differently. We use Participatory Risk Mapping (PRM) as an analytical tool to measure and identify the local ranking, frequency, and coping strategies for perceived risks in four communities in north Ghana. For every community we gather data from four focus groups with five participants. The groups are divided by the participants' gender and economic endowment. The data allows us to compare groups of individuals between and within the four communities. We identify patterns in inter- and intra-community characteristics which are linked to risk perception. By focusing on the characteristics we collect additional data to test and support our findings. The results indicate that communities exposed to similar environmental challenges are perceiving risks in agriculture differently. Furthermore, the perceptions of groups within communities vary widely. On the inter-community level the accessibility to lucrative markets for selling and networks outside of the community have a major impact. Culturally defined roles of men and women and coping strategies are the most influential characteristics on the intra-community level. Coping strategies depend on the prevalent sharing system for labour and goods but also on business opportunities apart from farming. The results underline the complexity of communities in northern Ghana. Similar risk reduction interventions can have diverse impacts within and on communities. The identified non-environmental characteristics provide a systematic approach to understand the diversity of communities and its influence on risk perception in agriculture.

**Keywords:** Agriculture, risk perception, rural development

## Subjective Measurement of Resilience of Agricultural Systems to Increased Salinity Intrusion in Vietnam

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The resilience concept has provided a new insight and approach to the conventional perspective of agricultural management by emphasizing the need to maintain a diversity of future options while increasing production efficiency to adapt to inevitable and often unpredictable changes. The concept has developed into various academic disciplines and covers a wide range of development sectors, yet ways to define and operationalize resilience as a practical and measurable concept are still being developed. This study combined a subjective resilience measurement based on the 5-point Likert scale of farmers' perception on the capacities of their agricultural systems to cope with and recover from salinity damage, and to change to other systems in the case of increased salinity intrusion with a qualitative resilience assessment. We conducted case study research in villages located along salinity transects in the Mekong delta and at different distances to sea dykes in the Red River delta in Vietnam. Empirical data consisted of interviews with local authorities, 11 focus group discussions, 118 semi-structured and 226 structured interviews and 3 role-playing games with farmers carried out between September 2015 and May 2016. Results from the subjective resilience measurement at the household level shows that there is no significant difference of resilience between farming systems ( $p\text{-value} < 0.05$ , Kruskal-Wallis test). None of the agricultural systems has a higher score than others of all resilience capacities, implying that an increase in one resilience capacity by switching systems would be achieved at the expense of other resilience components. Adjustment of resilience capacities e.g. through policies and interventions to sustain agricultural production or facilitate transformation to alternative systems when necessary is a critical task in agricultural management and will be discussed.

**Keywords:** Agricultural systems, salinity intrusion, subjective resilience, surrogates, Vietnam

## Climatic Changes in the Mid-Hills of Nepal: A Study on Smallholder Farmers' Perception and Reactions

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Climate and weather conditions in the mid-hills of Nepal have always been changing and local farmers have continuously adapted to such change. However, in recent decades these changes accelerated. The awareness of increased climate variability constitutes a prerequisite for adequate adaptation measures in the cropping systems. Hence, this study examined how farmers perceive climatic changes and whether their perceptions are confirmed by 35 years of records from two weather stations. Furthermore, farmers' reactions and - if any - targeted adaptations to perceived changes were investigated in order to assess their resilience to extreme weather events and ongoing climate change.

To this end, 60 formal semi-structured interviews were conducted with individual farmers in Kaule, a village situated in the Himalayan mid-hills, 25 km northwest of Kathmandu, Nepal. Half of the interviewees are members of a local non-governmental organisation (NGO) focusing on agroforestry. It was examined whether the time of residency in Kaule, education level, income sources and membership in the NGO had an influence on the perception of and the reaction to weather changes.

Farmers were generally well aware of changes in the local weather and their perceptions reflected the weather station records. Time series analysis proved a significant increase in both mean annual minimum and maximum temperatures. Absolute amounts of annual rainfall appeared to be stable with an average 2699 mm in 1981 – 1985 and an average 2679 mm in 2011 – 2015. Analysis in R found a decreasing, though non-significant trend. However, in accordance with farmers' perception, the annual distribution of rainfall did change, with longer dry periods during winter. While NGO members were primarily concerned about decreasing rainfall, non-members mostly mentioned abnormal weather patterns. The majority of farmers (59 %) did not implement targeted measures in response to weather changes; however, some farmers, especially members of the NGO, actively responded by delaying planting (27 %) or irrigating with spring, river, rain or domestic water (13 %). Promising adaptation measures suggested by the farmers were the storage of water in tanks and the reuse of domestic water for irrigation as well as the planting of trees and the protection of forests.

**Keywords:** Climatic changes, Nepal, perception, reaction, smallholder farmers

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## Analysing the Effects of Conflicts on Agricultural Production, Case of Nuba Mountains Region

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Links between environmental resources and conflicts are highly complex, non-linear and influenced by a combination of factors, including social, environmental, political, economic, historical, and the different aspects of vulnerability. Actually, the interaction of these factors plays a role in either preventing or stimulating conflict. Nevertheless, large open access natural resources can undermine the quality of governance, aggravate corruption, weaken economic performance and, thereby, increase the vulnerability of countries to conflicts. The changes in and depletion of natural resources linked to climate change have been considered as a causal factor in the current crisis in many regions of Sudan. The current study aimed to examine the effects of war on agricultural situation and macroeconomic situation of Nuba Mountains region. The methodology applied in this research was three-pronged: multi-temporal satellite data (i.e. LANDSAT) to examine the changes in land cover and land use, with primarily paying attention to changes in vegetation health, vegetation land changes, as well as the abandoned and agricultural land loss during the period 1994 to 2014. Furthermore, formal literature reviews, and semi-structured interviews of household heads. The total sample size was 175 questionnaires, covering displaced and non-displaced respondents distributed among different units of Nuba Mountains and the Nubian displaced community in Khartoum state. Geographic object-based image analysis was applied to analyse the satellite data. Normalized difference vegetation index and green normalised difference vegetation index were used as main features to guide the analysis. Qualitative and quantitative techniques were used to analyse the socio-economic data. The study indicated that, there are reduced and failure in agricultural yields, as well as loss of livestock, which endangered both pastoralists and rural peoples. Moreover, loss of arable land was due to bombardment and soil erosion. The study showed increasingly rapid changes in social structure, institutional and livelihood transformation across broad areas of the state. In sum, the successful key to face the impacts of environmental change need to create dynamic innovation research, strategies, and policy that focus on local communities to avoid the hazard of marginalising those who rely on natural resources for subsistence and income generation.

**Keywords:** Agricultural production, conflicts, geographic object-based image analysis, macroeconomic situation, Nuba Mountains region

## Perspectives of Stakeholders Towards the Development of Ecotourism as Collective Actions of Sustainable Collaborative Management in Kerinci Seblat National Park, Sumatra, Indonesia

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Regions around preservation and conservation areas, such as national parks, are vulnerable to conflicts, especially, between local communities and conservation managers. In consideration of this problem it is necessary to unify the stakeholders in the context of collaborative management to support pathways to sustainable management. In collective collaborative management all stakeholders do not only work for their own success, but share responsibilities for the task of the other actors at the same time. Conceptually the determination of ecotourism as a collective action has been examined with the adaptive collaborative management approach referring to the governance theory and the common pool resources theory. In detail this research focuses on the pattern of collective actions among the interest groups in the Kerinci Seblat National Park (KSNP) area. The study was conducted in four selected villages surrounding the park. The villages represent northern and southern parts of the Kerinci Regency. Secondary and primary data were collected by some methods such as participant observation, focus group discussion, open discussion, participant rural appraisal, and in depth interview. Data was analysed by qualitative content analysis, institutional analysis and development, and interpretative – qualitative technique.

The research results show that ecotourism can be a foundation for the formation of collective action in the context of collaborative management around the National Park area. But based on the empirical field study it can be stated that the local communities are not interested in the development of ecotourism due to contested property rights and utilisation interests in the area. Therefore, this research proposes that the local government and the KSNP authority should not only play a primary role regarding the development and the management of ecotourism, but also should be the primary drivers of the movement, which ultimately invites the local communities to initiate their collective actions.

**Keywords:** Collaborative management, collective action, ecotourism, Indonesia, Kerinci Seblat National Park, sustainability

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## Natural Hazard Mitigation Strategies Review: Actor Network Theory and the Eco-Based Approach Understanding in Zimbabwe

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This paper presents the literature reviewed on the evolution of the natural hazard mitigation perspective and an overview of its progression to date. It demonstrates how the Actor-Network Theory (ANT) theoretical framework can be applicable to Muzarabani in Zimbabwe as a tool for analysing and elaborating hazard mitigation strategies. ANT is gradually becoming influential, but still a bone of contention mainly because of its radical approach. ANT treats humans and non-humans as equal actors. In spite of its limitation, studies have shown that an ANT grounded approach is useful in providing a framework for the comprehension of the complexities of daily life during natural hazard episodes and the dynamic role of *Ziziphus mauritiana* in the network in Muzarabani of Zimbabwe. The theory can demonstrate its importance in respect of how social results are produced as a result of linkages among diverse actors (human and non-human) in a network. The chief significance of this consideration is that ANT offers a lens through which to assess the role of *Ziziphus mauritiana* as an actor in determining social processes and relations. Attention to this decisive role can contribute to an all-inclusive appreciation of the complexity of actors in semi-arid regions. *Ziziphus mauritiana*, an eco-resource, like other non-human phenomena, is introduced as an important and neglected actor in natural hazard mitigation discourse. Literature accessed has also affirmed that ANT can also demonstrate the dual value of rendering a theoretically informed method of sampling by mapping on actors that are linked to the eco-resource in question, *Ziziphus mauritiana* and analysis. The paper draws on contemporary empirical work in Muzarabani and the recurrent nature of natural hazards in this semi-arid landscape to explain noticeable results of the interactions between the human and non-human actors in hazard mitigation. The paper argues that if ANT is used logically it is useful in examining eco-based natural hazard mitigation approaches in semi-arid regions.

**Keywords:** Actor network theory, adaptation, commodity chain frameworks, ecological, hazard mitigation

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## Forward Looking Prioritisation of Farmer Innovation for Climate Change Adaptation in Cocoa Production in Ghana

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Prioritisation of climate change adaptation is challenged by the heterogeneity of projected hazards across space and farmers' resource endowments. Single adaptation solutions are unlikely and portfolios of commendable no-regret options should be developed. Site-specific scaling of farmer innovation may make wide adoption feasible but requires the reconciliation of top-down climate impact modelling and bottom-up participatory development processes.

First we developed a gradient of climate change impacts and assessed projected risks to cocoa production in Ghana from global climate models. We then conducted a series of focus group discussions and individual interviews to gather farmer innovation to manage climate risk along this gradient. The efficacy of these innovation options was verified by expert panels. For each impact zone, and for different household typologies, hazard specific sets of hierarchical portfolios with incremental returns and required effort were developed in focus group discussions.

We followed the notion that model based approaches in isolation will always fail to provide exact results, but may be useful to provide expert decision makers with a tool to prioritise concepts. This may be especially useful for tropical crops that often depend on adequate precipitation for which climate projections are highly uncertain. The result were portfolios of climate smart adaptation practices from farmer innovation with positive returns that respond to site specific climate hazards. We suggest that our approach may be a pragmatic way to develop site-specific climate smart practices for scaling. Practices will be included in training materials for certified farmers to be field tested as a pilot for sector-wide application. If successful an additional 93,000 households may remain in cocoa and about 430,000 would diversify production while keeping area under cocoa.

**Keywords:** Climate smart agriculture, cocoa, *ex-ante*, Ghana



# Institutions and livelihood

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## Oral Presentations

- ORKHAN SARIYEV, TIM K. LOOS, MANFRED ZELLER:  
**Gender Aspects of Intra-Household Decision-Making and its Effects on the Social Expenditure Patterns of Ethiopian Households** 502
- CLAUDIA RINGLER, DIRK WILLENBOCKEL, TINGJU ZHU, MARK ROSEGRANT:  
**Food-Energy-Water Nexus: What Would Be the Impact of a Carbon Tax?** 503
- DIETMAR STOIAN, MARLENE ELIAS, ALDO RODAS:  
**Land, Livelihoods and Gender: Dynamics of Community Forestry in Petén, Guatemala** 504
- DIANE KAPGEN, LAURENCE ROUDART:  
**Smallholder Farmers' Adaptations of Agroecology in the Context of Livelihood Asset-Deprivation: Social and Ecological Consequences in Bilanga, Burkina Faso** 505
- JULIANE GROTH, KATHLEEN HERMANS, PATRICK SAKDAPOLRAK:  
**The Influence of Land Degradation and Precipitation Variability on the Migratory Decision of Subsistence Farmers in Rural Ethiopia: An Empirical Study** 506

## Posters

- ERNESTINE MEFOR HALLE, REGINA BIRNER, ESTEPHANIA E. DELGADILLO JAIME, FRIEDER GRAEF, BARBARA SCHRÖTER:  
**Social Network Analysis of Stakeholder Groups Implementing Upgrading Strategies to Enhance Food Security in Rural Regions of Tanzania** 507
- ANNAPIA DEBARRY:  
**Food Sovereignty in Rural Myanmar: A Case Study on Drivers of Agrarian Transformation and impacts on Small-Scale Farmers** 508
- ZOLTÁN M. FERENCZI, WOLFGANG BOKELMANN:  
**Sustainability Assessment for Planning Development Interventions Within the Framework of the Sustainable Development Goals** 509

- BENEBERU ASSEFA WONDIMAGEGNHU, SARAH NISCHALKE,  
TECHANE GONFA ABEBIE:  
**Determinants of Farm and Non-Farm Employment among  
Smallholder Farmers in Yayu Biosphere Reserve, South-West  
Ethiopia: Implications for Future Agriculture?** 510
- CHARLES PETER MGENI, STEFAN SIEBER, T.S. AMJATH BABU,  
ZENA, T MPENDA:  
**Can Sub-Saharan Africa Become Food Self-Sufficient?  
Supply Response Analysis of Sunflower Oil Producers in  
Tanzania** 511
- ESSA CHANIE MUSSA, ASSEFA ADMASSIE, ALISHER  
MIRZABAEV:  
**The Effects of Childhood Work on Adult Migration and  
Occupational Structure in Rural Ethiopia** 512
- NICOLAS PATT, GUNDULA FISCHER, ANDREAS GRAMZOW,  
PHILIP JOSEPH:  
**Gender Dynamics in Smallholder Vegetable Production:  
Insights from Tanzania** 513
- NONJABULISO SIMELANE, ROLAND HERRMANN:  
**Consumption Patterns and Welfare Implications of the Maize  
Policy in Swaziland** 514
- KELEMEWORK GELETA GEBEYEHU:  
**Impacts of Cash-Transfer Program on Village Economy in  
Ethiopia: Village General Equilibrium Modelling Approach** 515
- ALEXANDER NII ADJEI SOWAH:  
**Socio-cultural Norms and Smallholder Adaptation to Climate  
Change in the Transition Zone of Ghana** 516
- SELAM HAILEMICHAEL:  
**The Role of Gender in the Sustainable Intensification of Agri-  
culture** 517
- NICOLE PAGANINI, ANJA SCHELCHEN:  
**Urban Agriculture for Food Security and Income Genera-  
tion: The Case of Maputo and Cape Town** 518
- HENNING KRAUSE, ANJA FASSE, ULRIKE GROTE:  
**Livelihood Strategies and Food Security - A Comparison  
between Rural and Peri-Urban Kenya** 519
- MST. TANIA PARVIN, REGINA BIRNER:  
**What Are the Governance Challenges of Microcredit  
Programs in Bangladesh? The Case of a Specialised Govern-  
ment Credit Program** 520

EMILIE PERROUSSET, DIRK LANDMANN: <b>Promoting Agroecological Practices among Cambodian Smallholder Farmers - Which Incentives Work?</b>	521
NICOLAS JOSE MESIA ROJAS, JÜRGEN PRETZSCH, YVES ZINNGREBE, PEDRO DANIEL PARDO VILLEGAS: <b>Incentives for the Implementation of Agroforestry Concessions: Experiences from Communities in the Peruvian Amazon</b>	522
STEPHANIE LEDER, MANITA RAUT, PANCHALI SAIKIA, FRASER SUGDEN: <b>The Feminisation of Agriculture in South Asia: An Opportunity for Farmer Collectives?</b>	523
CHARLOTTE WIEDERKEHR, KATHLEEN HERMANS, RALF SEPPELT: <b>Meta-Analysis of Rural Household Adaptation Strategies to Environmental Change in Sub-Saharan African Drylands</b>	524

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## **Gender Aspects of Intra-Household Decision-Making and its Effects on the Social Expenditure Patterns of Ethiopian Households**

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Decision-making is a widely used measure of women empowerment. Studies using this proxy to capture bargaining within a household usually neglect the possibility that all household members may actively participate in household decision-making. Measuring decision-making in a wider context than just a process of husband and wife's bargaining over decisions is much more appropriate and yet, insufficiently analysed. Based on a sample of 378 Ethiopian households, this study addresses this shortcoming and in addition, assesses the effect of decision-makers' gender on the social expenditures of the households, i.e. spendings directed towards education, clothing, health, and remittances. In detail, objectives are to (i) develop an index that captures the decision-making power of (all) women within a household, hence addressing the methodological gap present throughout the literature; and to (ii) estimate the effect of women's increasing decision-making power on the social expenditures of the households which may lead to positive effects on the households' livelihood. Covering seven fields of household decision-making (i.e. animal purchases, use of income from animal sales, agricultural technology adoption, household purchases, crops grown, harvest use, and input use), the variable information captures the possibility of decisions being made by single, two, or more individuals. By means of principal component analysis, a suitable index referred to as Women's Participation in Decision-making Index (WPDMI) is developed. Using this index as the main independent variable of interest, a log-linear model is employed to identify the effect of increasing women's decision-making power on the households' social expenditure patterns. All validity tests yielded positive results meaning that the newly developed WPDMI index sufficiently captures and reflects the empowerment information contained in the decision variables. Moreover, the findings show that an increasing women participation in household decision-making processes results in positive and significant effects on the per-capita social expenditures of the households. As a whole, this study offers an approach to address the methodological gap in the analyses of decision-making throughout the literature. It further confirms previous findings of positive effects of women's increasing decision-making power on the household's livelihoods.

**Keywords:** Decision-making, Ethiopia, social expenditure, women empowerment

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## Food-Energy-Water Nexus: What Would Be the Impact of a Carbon Tax?

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The food, energy and water sectors are inextricably interlinked and face many common challenges in an era of growing natural resource scarcity, increasing environmental externalities, and lack of good governance. The importance of those linkages can be further seen through the adoption of the Sustainable Development Goals, which includes a set of goals and targets on food (SDG2), water (SDG6) and energy security (SDG7). It will be extremely challenging to achieve these goals equitably, efficiently and by 2030 due to important interlinkages and growing natural resource scarcity. This paper assesses implications for the nexus based on changes from the energy side: among the three sectors, the energy sector is most dynamic and while many linkages between the food and water sectors have been studied, energy has been neglected. This study assesses the impact of a carbon tax on fossil fuels on food and water outcomes.

We find that changes in the energy sector in response to a potential carbon tax that reduces the relative comparative advantage of fossil fuels particularly affect those regions that are both net exporters of primary fossil fuels and net importers of refined petrol, such as East and West Africa, but that impacts on global food prices are limited. The number of people at risk of hunger would increase by 9 million people in response to the carbon tax, with the largest increases changes in the South Asia and sub-Saharan Africa region. At the same time, the carbon tax would increase the share of unmet water needs in all regions of the globe due reduced household incomes. Importantly, depending on the adaptation measures chosen in response to the carbon tax, the food and water security situation could substantially worsen, for example, if biofuel areas are expanded to compensate for the reduced use of fossil fuels under the carbon tax. Under such a scenario the number of people at risk of hunger by 2050 could be 31 million higher. On the other hand, to the extent that the reduction in fossil fuel use due to carbon taxes lessens climate change, these taxes can improve food security substantially.

**Keywords:** Energy, food, water

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## Land, Livelihoods and Gender: Dynamics of Community Forestry in Petén, Guatemala

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In the Maya Biosphere Reserve in Petén, Guatemala, about 350,000 ha of forest have been granted as community concessions since 1997. Each of these concessions is operated by a community forest enterprise (CFE) which is responsible for sustainably managing the forest and sharing the resulting benefits among members. In coming years, all currently nine active concessions will be considered for renewal contingent upon their environmental and socio-economic performance. In contribution to this assessment, this study provides scientific evidence on: 1) socio-economic benefits, 2) gendered access to resources, and 3) opportunities for enhancing gender equity and, overall, viability of the concessions.

Adopting an asset-based approach, we initially studied the socio-economic performance of three concessions in 2014/15 using the 5Capitals methodology. In 2016/17, we expanded the study to three further concessions in which we tested a gender-responsive version of the methodology (5Capitals-G) to elucidate gender-based constraints and opportunities in the CFEs and the value chains they are linked to.

Concession benefits at enterprise and household levels were significant, but varied widely across CFEs (n=6) and households (n=170). At enterprise level, asset building was most pronounced as regards natural, social and physical capitals. Human capital was well developed for managing forests, but less so for processing wood and doing business. All enterprises were profitable, but their financial capital varied. Men dominate CFE governance, but women are increasingly shaping business decisions. At household level, forest income allowed CFE members to move above the (extreme) poverty line and to develop their physical and human capital. Labour was strongly divided by gender, with men primarily focused on timber and women on non-timber forest products. Women's influence on household decisions and control over resources varied widely. Most CFEs lack strategies to involve younger women and men in forest management and business administration. This threatens the long-term prospects of the CFEs, as do competing claims on the land by external stakeholders. We argue that the community concessions should be renewed as they contribute to both forest conservation and livelihoods development, and conclude with opportunities for enhancing this model and scaling it elsewhere in Latin America and beyond.

**Keywords:** Asset building, community forestry, forest enterprises, gender, Guatemala, livelihoods, Petén

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## Smallholder Farmers' Adaptations of Agroecology in the Context of Livelihood Asset-Deprivation: Social and Ecological Consequences in Bilanga, Burkina Faso

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In the sudano-sahelian climate zone of eastern Burkina Faso, the local NGO ARFA – Association pour la Recherche et la Formation en Agro-écologie – implements smallholder-tailored development programs based on improved agroecological farming practices and small farm equipment diffused through village-level operating farmer groups.

A qualitative research design was used to analyse how agroecology impacts on different smallholders' livelihoods and which factors shape benefits and adverse effects. We relied on the sustainable livelihoods framework and further completed it with a) the francophone agronomy-based *Agriculture Comparée* approach to better investigate the farming systems level, and b) the development-anthropology ECRIS (*Enquête Collective Rapide d'Identification des conflits et des groupes Stratégiques*) related concepts to gain in-depth understanding of social structures, power relations and conflicting interests.

Depending on the strength of their livelihood asset base and their personal livelihood strategies, farmers use different logics of action when engaging in the programs. Asset-endowed farmers hold leading positions in the farmer groups and have a wider range of possibilities for appropriating the program's elements to their advantage. Program-related ignorance of smallholders' unequal starting positions create both ecological and social discrepancies. They hit asset-deprived farmers and fragile ecosystem components at the same time. Insufficient access to small equipment for implementing labor-intensive water-harvesting-techniques (stone bunds and Zai) hinders equipment-deprived farmers' adoption, thus contributing to the spreading of unfertile soil (Zippélé). Lack of local plant nurseries for agroforestry land management intensifies the practice of uprooting saplings in the bush for replanting them in the fields, leading to both the loss of trees in uncultivated ecosystems and more fragile field trees compared to plants from tree nurseries. Livestock herd size limits farmers' capacity to gain excreta necessary for the intensively promoted compost production technique. Livestock-poor farmers' children browse the bush collecting the excreta from trespassing herds, contributing to both children's exploitation and removal of valuable natural fertiliser from the bush. Water quantities needed for compost production clash with the need for drinking water in the dry season. These examples outline our study's contribution to understanding the complex social-ecological interactions in agroecological development programs, which are shaped by smallholders' diverging livelihood asset bases and opportunities to appropriate the programs' elements.

**Keywords:** Adaptation of agroecological practices, Burkina Faso, farmer diversity, livelihood impact, rural development programs, social-ecological trade-offs

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## The Influence of Land Degradation and Precipitation Variability on the Migratory Decision of Subsistence Farmers in Rural Ethiopia: An Empirical Study

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Migration can be one strategy of subsistence farmers to sustain, adapt or transform their livelihoods under changing environmental conditions. The sustainable livelihood approach (SLA) is well suited to tackle questions within the field of environmental change and human migration, as migratory decisions often emerge at the individual or household level. For Ethiopia the depletion of natural resources and climate variability is observed in large parts of the country and local case studies revealed the influence of environmental change on out-migration, usually in combination with socio-economic and political factors. But so far there is a lack of knowledge how these factors which shape the decision to adapt, for example through migration, or to stay are interrelated.

The presentation will focus on the research design for an empirical study which will be conducted in South Wollo end of 2017. South Wollo is an out-migration area in the northern Ethiopian highlands, where precipitation variability, population pressure, land degradation and food insecurity are well known as putting the livelihoods of the rural population under pressure. By applying mainly semi-structured interviews and focus groups with local farmers and regional key informants, the research aims to 1) understand the livelihood strategies of subsistence farmers to deal with environmental changes, 2) identify the (in)direct influence of environmental change on out-migration and the interrelations with other factors and 3) examine what hampers or triggers the migratory decision of the farmers. The local data collection will take place in eight villages which differ in terms of severity of land degradation and livelihood strategies. Moreover, preliminary findings from a preparatory field visit in spring 2017 will be presented.

Being part of a dissertation project this empirical study is considered as a first crucial step to shed light on the complex interrelations between environmental change and human migration in the tropics and aims to support stakeholders and policy makers in Ethiopia. This study is part of the interdisciplinary junior research group MigSoKo (<https://www.ufz.de/index.php?en=41462>), which is based at the Helmholtz Centre for Environmental Research in Leipzig.

**Keywords:** Climate variability, Ethiopia, human migration, livelihoods

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## Social Network Analysis of Stakeholder Groups Implementing Upgrading Strategies to Enhance Food Security in Rural Regions of Tanzania

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Improving food security is essential for most rural Tanzanian households where the nutritional status of the country's population is low. Given the challenges of rising food demand it is highly recommended to upgrade existing smallholder food systems against upcoming vulnerabilities. The aim of this study was to assess and apprehend the role of actors and the interlinkages among the upgrading strategy/ies (UPS) groups; to determine the relationship within these UPS group actors; to recognise the differences between the different UPS groups and other actors; and to define possible success factors for UPS group performance. The study was conducted in the framework of a multi-disciplinary Trans-SEC project in Tanzania, designed to enhance food security for rural poor households by employing food securing UPS along the food value chain. Our specific focus was on two UPS, namely a) tied ridges and fertiliser micro dosing b) maize sheller and millet thresher.

Research methods included individual interviews using the social network analysis tool Net-Map and focus group discussions. The Net-Map tool enabled visualising and understanding the power relations, interlinkages among the UPS groups, and stakeholder goals, all of which facilitate knowledge transfer and material flow. The results show that most UPS in the sub-humid region had slightly higher knowledge network densities in contrast to those in the semi-arid region. The knowledge, money and material flows were similar among different groups. Motivations for participating in a UPS group differ to some extent between UPS groups and all types of actors whereby enhancing food availability, more joy, more income, more knowledge and better social relations were most frequently mentioned. The results provide understanding of the different UPS stakeholder group's performances by showing attributes of stakeholders and then relating them to their goals and perceived influence. The results further provide the basis for future strategic planning to further enhance participation and up-scaling. This study suggests that improved performance along the food value chain is needed, investments in policies, capacity building for farmers and social learning in terms of collective action and collaboration. The study serves as a landmark for understanding stakeholders' roles and their influence in implementing upgrading strategies.

**Keywords:** Degree centrality, food value chain, motivations, Net-Map, stakeholders

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## **Food Sovereignty in Rural Myanmar: A Case Study on Drivers of Agrarian Transformation and impacts on Small-Scale Farmers**

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With the economic opening of Myanmar the commercialisation of agriculture is one of the main goals of the government. Small-scale farmers in Myanmar are struggling with these commercialisation processes: Pro-business land reform and local power structures along with foreign investments in export-oriented, large-scale agriculture are undermining local food systems and customary land tenure rights pushing small-scale farmers into deeper poverty and wage-labour. The food sovereignty (FS) approach aims to return power and control over the food system to producers and consumers. This paper introduces the results of a field research which was conducted in two villages in southern Shan State and puts small-scale farmers and their struggles over land, food and rights at the centre of discussion by using the approach of FS to examine the factors which are pushing commercialisation. Moreover, it explores aspects of the academic discourse on FS and gives critical insights. Data was collected with a mixed-method approach. Qualitative methods were taken from the Participatory Rural Appraisal (PRA) tool box, including transect walks and seasonal calendars. The methodology also included gender-disaggregated focus groups discussions, semi-structured interviews with village residents and key-informants. A household survey (n=60) was conducted in both villages to back up the qualitative data. Data was analysed along three key factors, namely food security and farming situation, access to land and migration and labour. Through this broad perspective, the research identified a variety of interrelated factors negatively influencing the local FS. Results show that farmers are forced to stay in a “circle of poverty”: Food insecurity is fostered by pro-business policies introduced by the government and external stakeholders who increasingly control local resources. It was found that the commercialisation of agriculture (e.g. through hybrid crops and large-scale cultivation) plays an important role in the struggle of small-scale farmers. It is argued that although the academic discourse on FS has to be deepened on some levels (e.g. the relationship between FS and capital-state power relations), it is an important contribution to somewhat radical thinking on development as it puts those at the heart of discussion who are undermined by neo-liberal policies and state-driven power relations.

**Keywords:** Agrarian Question, capitalism, contract farming, food security, food Sovereignty, hybrid crops, Myanmar, small-scale farmers

## Sustainability Assessment for Planning Development Interventions Within the Framework of the Sustainable Development Goals

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With the adoption of the Sustainable Development Goals (SDGs), the United Nations have internalised a set of features for future development which are to circumvent known shortcomings of the Millennium Development Goals and set binding rules also for the industrialised countries. Particularly influential for the shaping of the underlying principle of SDGs was the concept of “planetary boundaries”; a scientific normative compass envisaging a human development process which does not transgress the point of no return in terms of the Earth’s life support systems. Integral to the idea of coupled “natural-social” systems, is the concept of inter- and transdisciplinarity; i.e. that solutions to complex problems and preceding research must be based on integrative efforts of traditionally separate disciplinary areas and with full participation of stakeholders.

While this broad approach to sustainable development has largely been accepted by the international community, accountability remains left to national governments. Hence, there has been significant criticism that this type of diversity will allow room for much obscurity and strategic “cherry-picking” when designing policy interventions, ultimately resulting in suboptimal outcomes in terms of interdisciplinary and integrative approaches.

Given the lack of internationally set accountability mechanisms with regard to the SDGs, we are proposing an *ex-ante* impact assessment method to be used. It could be used to evaluate projects prior to their setup and funding approval along the lines of SDGs rather than the nationally readapted goals that are derived by the individual governments.

As a case study, we apply this *ex ante* assessment methodology to an ongoing international transdisciplinary research effort, aiming at improving rural and urban livelihoods in Kenya by developing the sector of indigenous vegetables. Systematically evaluating the project activities against the 169 SDG targets using a relevancy scoring system provides a reproducible and simple but comprehensive overview of the areas where significant SDG contributions are to be expected and where less so.

**Keywords:** *Ex ante* assessment, Kenya, SDGs

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## Determinants of Farm and Non-Farm Employment among Smallholder Farmers in Yayu Biosphere Reserve, South-West Ethiopia: Implications for Future Agriculture?

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Enhancing agricultural productivity has remained to be one of the major challenges in sub-Saharan Africa, where Ethiopia is not an exception. Although agriculture is the main stay of the Ethiopian economy contributing for half of the GDP and 50% of exports, the sector is characterised by its subsistence nature and incapacity to attain food and nutrition security at national level, resulting small holder farmers to diversify their livelihoods to non-farm employment as a coping strategy. This study aims at analysing the determinants of farm and non-farm employment for smallholder farmers in Yayu biosphere reserve of South-West Ethiopia. A household survey was undertaken to collect gender disaggregated data from 334 small holder farmers and supported by qualitative data collected from 28 Focus group discussions and 6 key informant interviews. Gender disaggregated tobit regression analysis followed by marginal effect computations were employed to capture the probability and extent of determinant variables in predicting farm and non-farm employment. Augmented production factors particularly farm physical capital and land ownership along with total agricultural productivity have been found to increase the probability and intensity of farm engagement positively and significantly for both male and female headed households. For every unit increase in total agricultural productivity, there has been a 2.1% and 4.3% increase in the extent of farm engagement for both male and female headed households, respectively. Similarly, the level of farm engagement increased significantly for every unit increase in farm land, farm physical capital, access to credit and irrigation, ownership of non-farm assets and labour support system practised in the area. On the contrary, a higher level of education, increment in non-farm income and household expenditure, incidence of crop damage by wild animals as well as pests and diseases were found to influence farm engagement negatively and increased non-farm employment significantly. The results implied that engagement in farm is highly dependent on availability and efficient use of scarce farm production factors, productivity of the farming sector and the presence of external farm challenges. These call for sustainable and holistic approaches to improve the future productivity of small holder agriculture.

**Keywords:** Agricultural productivity, determinants, farm employment, non-farm employment, production factors, South-West Ethiopia

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## Can Sub-Saharan Africa Become Food Self-Sufficient? Supply Response Analysis of Sunflower Oil Producers in Tanzania

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There are many arguments that, increasing food self-sufficiency in sub-Saharan Africa (SSA) could reduce the high food price escalations which are often related to the increasing demand and importation of food commodities. In Tanzania, as in most SSA countries, edible oil crops production has been among the most vibrant activities, as there has been rapid expansion in the production of oil crops with high protein content, such as soybean, groundnuts, rapeseed and sunflower seeds. These crops are used largely for direct oil consumption, with their residues used as animal feed. Currently, annual edible oil demand is around 400,000 tons, a figure that is increasing at a rate of 3 % annually mainly because of population growth and increased health concerns. Current data shows that domestic production of both factory and small-scale extracted edible oils contribute to about 40 % of the national edible oil requirement while the deficit is imported. However, among the edible oil seeds, sunflower subsector dominates the supply of edible oil. In this study, an attempt has been made to examine the supply response of sunflower edible oil sub-sector against imported palm oil by using the Nerlovian partial adjustment model. Findings indicate, that the short-run price elasticities for sunflower oil and palm oil were -0.0028 and -0.396, while the long-run elasticities were -0.0045 and -0.64, respectively. On the other hand, short and long run elasticity for farmer income were 5.54 and 8.99, respectively. The speed of adjustment of per capita sunflower edible oil consumption was relatively high with 61.4 % per period. This high adjustment perhaps indicates that Tanzania sunflower edible oil sub-sector, with its predominantly smallholder farmers for raw material production, and small and few medium oil processors, may not be having enough capacity in terms of resources and technology to immediately increase sunflower edible oil production to self-sufficient level when the economic milieu improves in their favour. This calls for the Tanzania Government to review the tax policy on the imported agricultural technologies and other materials which increase costs for farmers and processors. This could enhance to achieve her self-sufficient endeavour.

**Keywords:** Self-sufficiency, sunflower edible oil, supply analysis, Tanzania

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## The Effects of Childhood Work on Adult Migration and Occupational Structure in Rural Ethiopia

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The rural parts of Ethiopia and its agricultural sector went through dramatic changes in the last decade. However, dwindling farmlands and underdeveloped non-farm sectors coupled with unmatched population growth continued to define its rural areas. Empirical evidence show that rural youth are abandoning agriculture and leaving the rural areas, despite limited gainful employment opportunities are available outside agriculture. In this regard, studies that examine rural out-migrations from the perspectives of spatial and sectoral wage-gaps and expansion in job opportunities fail to provide important insights and guide policy regarding the youth out-migrations witnessed in Ethiopia since early 2000s. In this paper, we argued and provided evidence that rural out-migration might also be driven by childhood conditions and develop over time to adulthood in addition to other observable factors at a point in time.

Using two-wave panel dataset, separated by 15 years, we examined the effects of childhood work and school participation of 4 to 14 years old children in 1999/2000 on their out-migration and occupational structures as of 2015/2016 in rural Ethiopia. The results showed that while village out-migration during this period was dominated by females and younger members, economic (labour) out-migration, in particular, was male oriented. More importantly, children who combined work with schooling were highly likely to out-migrate from the villages. We argued that childhood work when combined with schooling, in consonance with human capital theory of migration, may provide children the opportunity to acquire transferable and marketable skills and build their entrepreneurial spirit leading to aspire to out-migrate and work in non-farm activities. Contrary to the risk and poverty hypotheses of migration, household poverty showed insignificant association with children's migration. The effects, however, were heterogeneous by gender and birth order. The occupational trajectories and earnings revealed that about half of migrants worked in non-farm activities and earned twice as much as non-migrant earnings.

The findings suggest that to ensure labour migration as engine for structural transformation and improve labour market outcomes, policy makers need to link early human capital policies such as child schooling with youth-targeted labour market policies. Moreover, anti-poverty policies alone may not regulate rural out-migrations.

**Keywords:** Child schooling, childhood work, migration, non-farm works, occupations

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## Gender Dynamics in Smallholder Vegetable Production: Insights from Tanzania

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The presented study investigates gender dynamics in vegetable producer's households as related to labour, income and expenditure allocation – as field that has not yet been sufficiently covered by research. It is conducted under the “Africa Research in Sustainable Intensification for the Next Generation” (Africa RISING) project funded by the United States Agency for International Development (USAID) and led by the International Institute of Tropical Agriculture (IITA). The study focuses on farmers in Babati, Kiteto and Kongwa districts in northern and central Tanzania.

Quantitative data was collected during a survey with 400 male and female farmers in nine villages. Later on, we conducted focus group discussions with sex-separated farmer groups and expert interviews with male and female extension officers. Thus, we validated the quantitative data, investigated on underlying causes for gender inequalities and identified entry points for additional research and development interventions.

The survey results show that men and women have different perceptions of labour, income and expenditure allocation within the households. Following this, the qualitative research revealed that both men and women keep information on their individual income confidential in order to strengthen their position in intra-household negotiations. Moreover, both complain about their partner's lack of contribution to the household economy and production activities. Nevertheless, both qualitative and quantitative data indicate that men have higher income and are in power when it comes to money-related decisions, while women remain economically dependent. Women explain their dependence with men's control of access to land, financial capital, knowledge and markets. Men on the other hand named women's physical limitations and poor money management skills as reasons that prevent them from progressing economically through vegetable farming. Both stated that domestic labour prevents women from getting more involved in farming activities.

The analysis shows that distrust and low cooperation within the households constitute obstacles for food security, poverty alleviation and women empowerment. Therefore, we emphasise the necessity of including men in gender-transformative approaches in agricultural research and development.

**Keywords:** Gender dynamics, income security, smallholder agriculture, vegetable production, women empowerment

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## Consumption Patterns and Welfare Implications of the Maize Policy in Swaziland

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The domestic food policy in Swaziland has been linked to high and rising food prices especially, maize and maize meal prices. As a food grain that is of significant importance for food security in Swaziland, the price of maize has important welfare implications on household welfare. This is of particular importance when we take into account the potential risks associated with import dependence as Swaziland is highly reliant on imports to meet domestic demand for basic staples in particular. Moreover, maize expenditure accounts for over 20 % of poor households' income as well as maize accounts for 63 % of calorie intake in the country. This suggests that severe price movements in the maize market negatively influence the food security and nutritional status, especially for vulnerable, low-income households that spend a substantial proportion of their income on food. On the other hand, high prices of agricultural products have the potential to increase rural incomes and food security levels, resulting from positive production effects. The current study therefore, analyses the food consumption patterns of rural households in Swaziland using a QUAIDS model to obtain the estimates of price and expenditure elasticities for major food items consumed. The estimated elasticities are subsequently used to evaluate the distributional effects of the maize policy changes on household welfare through the compensating variation welfare measure. The results of the study suggest that majority of the food items are demand inelastic with meat and dairy exhibiting elasticities greater than 1. Moreover, the results of the study indicate that poor households are the major beneficiaries of maize market liberalisation as they spend a larger share of their food budget on maize. However, lowering the price of maize may have potential risks to net selling households, by discouraging production in the long-run. Therefore, policy strategies should focus more on expanding agricultural production and diversification of production activities, which can improve household income as well as stimulate food demand in Swaziland.

**Keywords:** Consumption patterns, food prices, household welfare, Swaziland

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## Impacts of Cash-Transfer Program on Village Economy in Ethiopia: Village General Equilibrium Modelling Approach

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Cash transfer programme is designed to address poverty and considered as an engine for rural economic growth in Ethiopia. Various studies have been conducted in relation to the impact of cash transfer programs. However, those studies focused on the impacts on beneficiaries (participants) while spillover effects of the programme remained understudied. The main sources of the data were the national social accounting matrix and 150 randomly selected households in the village of Harawobello, of which 75 are participants of the programme. The village is in an area where the level of poverty is deep rooted (50 % poor). Village level general equilibrium model has been applied to capture economy-wide impacts of the programme using various scenarios. The simulation results have indicated that the consumption expenditure of non-beneficiary households has been increased after removal of cash transfer program. Non-participant households benefited more from the decrease in price of commodities; the price effect outweighs the income effect. Complete removal of the programme leads to household welfare loss for beneficiary household groups while non-participants derive positive welfare gain due to price reductions. However, removal of cash transfer programme results in a net welfare loss of ETB 3900 from the village. Moreover, the micro simulation results confirmed that after the removal of the program, the incidence of poverty is increased by 4 %. The poverty gap and severity index have also risen by 5 % and 1 % respectively. The income inequality of households has been increased by 50 % and 20 % for cash transfer participant and non-participant household groups respectively. These call either to create other opportunities that link non beneficiaries to other agricultural projects to enable them coping with the increase in price or to improve their production.

**Keywords:** Cash transfer, village economy, village general equilibrium

## Socio-cultural Norms and Smallholder Adaptation to Climate Change in the Transition Zone of Ghana

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Climate change poses a lasting threat and its associated impacts are differentiated, affecting the livelihoods of men and women in different ways. The gendered differentiated impacts and experiences have been highlighted by both the United Nations Framework Convention on Climate Change and Food and the Agriculture Organization of the United Nations as very real, requiring clear strategies and inventions to address these. The Marrakech conference of 2001, in acknowledging the near permanent threat of climate change, stressed the need to enhance capacities to adapt to the impact and challenges societies are confronted with. A number of studies have shown that sub-Saharan African countries are particularly vulnerable to climate variability and climate change. The threats to individuals and collectives are deepened due to limited capacities to response to climate change and variability impacts. Increased exposure to impacts yet constrained ability to utilise adaptive options have been found to be context specific, finding expression in socio-cultural norms and practices governing rights and entitlements. This study explored the gendered outcomes of climate induced adaptation within four (4) communities in the transition zone of Ghana, with specific focus on the Nkoranza South Municipality. This study also examined the influence of socio-cultural norms and practices on pattern and direction of climate change adaptation of small holder farmers. Using a household survey with 384 participants and 8 focused group discussions organised separately for women and men, the work showed that in spite of the strong influence of contextual norms and practices, they do not only constitute barriers to adaptation but also provide opportunities for important alteration in livelihoods. These transformations and diversifications in livelihoods help to curb maladaptation and heightened sensitivities to climate change impacts. These transformations are however more likely to be undertaken by women as opposed to men, thus providing opportunities for women to increase their control of financial resources through their engagement in trading and other communally based economic activity. Additionally, non-farm, especially activities with low sensitivity to climate change and variability, have become reliable means through which livelihoods are sustained.

**Keywords:** Adaptation, climate change, contextual, cultural, gender, variability

## The Role of Gender in the Sustainable Intensification of Agriculture

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The sustainable intensification (SI) of agriculture is among the main paradigms guiding the 21<sup>st</sup> century agricultural transition in sub-Saharan Africa. SI proposes simultaneous achievement of production and productivity increase while reducing impact on the environment, and contributing positively to it. This paper explores the role of women's empowerment and gender relations in the decision to adopt SI related practices. It identified seven intensification and seven sustainability-enhancing practices and compared the decision to adopt these with the gender of plot managers and women's empowerment scores. Women's empowerment was measured using the component indicators of the Women's Empowerment in Agriculture Index (WEAI), which measures women's empowerment across five domains: production decision, resource use, income, leadership, and time use. Using plot-level production data from household surveys in two rural districts of Ethiopia, the study finds that there is an overall gender gap in the adoption of SI strategies, with male owned and managed plots consistently showing higher adoption levels of both intensification and sustainability enhancing practices. The study further finds that women's empowerment makes an important distinction in the composition of SI practices adopted. Households where women have higher empowerment score on resource use, income, and time use adopted more sustainability practices, while households with lower empowerment scores adopted more intensification than sustainability related practices. These findings confirm that gender plays an important role in the promotion of sustainable agriculture, where gender inequality and lower levels of women empowerment have environmental cost beyond economic ones which deserves critical attention. With these novel findings, the study recommends the contextualisation of SI as the guiding paradigm of the ongoing agricultural development should be done by paying particular attention to social and relational issues.

**Keywords:** Ethiopia, sustainable intensification, women empowerment

## Urban Agriculture for Food Security and Income Generation: The Case of Maputo and Cape Town

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The international community set the goal “Zero Hunger” as one priority in its global commitment of achieving the Sustainable Development Goals by 2030. Cities are growing fast but economically highly unequal and access to safe and healthy food remains problematic. Sub-Saharan Africa is the most rapidly urbanised region in the world, especially the urban informal areas are growing. In this context, urban agriculture has been a popular response in contributing to income generation and food and nutrition security and has come into the focus of scientific research.

Due to this, this research raises the question of the impact of urban agriculture, related to food security and possible income means for the disadvantaged urban communities in Cape Town and Maputo. Could urban agriculture be a solution to food security especially for cities in the Global South?

To tackle this question, the first representative household survey with urban farmers in Maputo has been conducted. In Cape Town a household survey with special focus on smallscale and market garden production as well as information exchange shows up urban gardening activities in different townships. The results of both surveys provide a picture of sociodemographic, socioeconomic, production and knowledge transfer data of urban farmers in both cities and set the base to analyse differences and commonalities.

Even if two realities are found in both cities – a comparative analysis allows to draw up recommendations about the role and meaning of urban agriculture in both cities and therefore to foster the scientific research in this area.

**Keywords:** Agroecological practices, food and nutrition security, impact, innovation system approach, Southern Africa, urban agriculture

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## Livelihood Strategies and Food Security - A Comparison between Rural and Peri-Urban Kenya

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With around 800 million people being undernourished and 2 billion suffering from hidden hunger, the global community is still very far from achieving the first two Sustainable Development Goals to eradicate extreme poverty and hunger. Despite a recent favourable economic development, Kenya ranks still among the top countries where hidden hunger is prevalent with around 20 % of all Kenyans being undernourished. It is thus imperative to investigate the characteristics of food insecurity in the Kenyan society. This paper explores the characteristics in a two-step cluster analysis, focusing on the structural differences of household income, livelihood strategies and asset distribution. It is based on data from the HORTINLEA Household Survey 2015, in which 700 vegetable producers have been interviewed - 200 rural producers each in Kakamega and Kisii County, and 150 peri-urban producers each in Kiambu and Nakuru County. To address the complexity of food security in its four dimensions, multiple food security indicators such as the Food Consumption Score, Household Dietary Diversity Index or Month of Adequate Household Food Provisioning have been used to group the households into food secure and food insecure households. Since the differences between rural and peri-urban Kenya are substantial in terms of public infrastructure and level of income, we separated and compared rural and peri-urban households in the analysis by using a dummy. Four clusters have been generated - one food secure and one food insecure one each in peri-urban and rural areas. Results show a significant higher prevalence of food insecurity in the rural areas especially in the utilisation and stability dimension. Food secure producers in the peri-urban area do have higher levels of education and own more land. However, both food secure and insecure households in peri-urban areas are better endowed with household assets such as cars or TVs. Food secure producers have more income from off-farm employment and less from crop production than food insecure ones. Interestingly, this is true for both rural and peri-urban areas.

**Keywords:** Cluster analysis, food security, Kenya, livelihood strategies

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## What Are the Governance Challenges of Microcredit Programs in Bangladesh? The Case of a Specialised Government Credit Program

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Bangladesh is well known for its micro-finance institutions (MFIs), which are widely recognised as an effective tool for poverty reduction and employment generation. Since the inception of micro-finance in the 1970s, a variety of MFIs has emerged in Bangladesh. Not all MFIs are equally successful, and there are important gaps on the factors determining their effectiveness. To better understand the governance challenges faced by MFIs, a case study was conducted that focused on a particularly interesting case: the Microcredit Scheme of the Bangladesh Handloom Board (BHB). The studied case is a specialised government-funded credit programme which provides microcredit to a specific non-agricultural household called handloom weavers in Bangladesh. The study attempted to examine the governance challenges from both the supply-side (the BHB) and the demand-side (the handloom weavers). Therefore, a participatory mapping method called Process Net-map was used to identify the governance challenges confronted by the supply-side stakeholders. In addition, key informant interviews were conducted to collect in-depth information on the studied issue from both groups of stakeholders. Finally, 'Content Analysis' technique was used to analyse and interpret the findings which was further guided by a conceptual framework to distinguish the challenges from both sides. The findings analysed from both of the perspectives reveals that the BHB Microcredit Scheme faces problems in allocating adequate resources to human and physical capacity development. This problem is further combined with a shortage of funds that make it impossible to meet the clients' expectations. Moreover, there is no adequate legal and regulatory framework to govern the stakeholders' activities. A further problem is the inability of the programme to control political influence and corruption in the system. Competition by the providers of informal credit sources also causes a problem. Moreover, the policy of lending only to groups proves counterproductive in this case, as it leads to the exclusion of potentially viable borrowers. Against this background, a reform of the organisational policy of the BHB programme is recommended. The paper also draws conclusions that apply more generally to microcredit programs that are run by government organisations.

**Keywords:** Bangladesh, key informant interview, process net-map

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## Promoting Agroecological Practices among Cambodian Smallholder Farmers - Which Incentives Work?

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Today, agroecology is a central issue in agriculture, as it enables more sustainable and resilient systems. Nevertheless, smallholder farmers may be reluctant to adopt agroecological practices; especially innovative ones, as they are knowledge-intensive and require investments which are perceived as risky, especially for the poorest farmers who are mostly women.

This paper investigates preferences of Cambodian smallholder farmers regarding incentives to adopt conservation agriculture practices in horticulture. It focuses more specifically on home gardens and small scale vegetable production in the northern province of Siem-Reap. The incentives considered are training, contract farming, technology (drip irrigation system), inputs (high quality seedlings) and financial services (microcredit).

The data were gathered during a discrete choice experiment involving two groups of farmers: the first group of 70 farmers was already part of a project providing incentives and had adopted conservation agriculture as a farming method., whereas the second group of 100 farmers consisted in vegetable farmers who had not adopted conservation agriculture yet. By comparing the relative value given to each incentive in the two groups, we obtained information about the needs of farmers already practicing conservation agriculture, as well as about the ideal design of a project aiming at convincing more farmers to switch their current practices to more ecological ones.

The results show that the incentives which farmers value the most are the access to microcredit and the access to technical know-how, consisting in the support of an agricultural technician and the organisation of trainings on specific topic, e.g pest management. By contrast, market access through contract farming as well as the use of technology, in our case a drip irrigation system, has a lower influence on the farmer's decision to adopt agroecological practices. Stakeholders involved in projects promoting conservation practices should thus concentrate their efforts on training and financial services in order to convince farmers.

**Keywords:** Cambodia, conservation agriculture, developing country, discrete choice experiment, drip irrigation, horticulture, incentives

## **Incentives for the Implementation of Agroforestry Concessions: Experiences from Communities in the Peruvian Amazon**

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Agroforestry concession is an important policy instrument to combat deforestation in the Peruvian Amazon. It authorises small and medium farmers to access in a sustainable way to forest and natural resources, in forest production or protection areas that present some degree of disturbance. The Forestry and Wildlife Law and its Regulation have established activities to support agroforestry systems and forest plantations in the context of agroforestry concessions. As the uptake of agroforestry concessions depends on farmers' decisions, incentive systems have to be adjusted to fit local sustainable production systems and farmers' preferences. This study seeks to identify and assess policy options that function as incentives for the effective implementation of agroforestry concessions according to their objectives as specified in the FWL and RFWL. It was carried out in the communities of Marisol, La Primavera, Nueva Esperanza and Gran Pajaten, in the province of Mariscal Caceres, San Martin department. 86 key stakeholders at the national, regional/local, and farm level provided crucial information through discussion meetings, individual interviews, and workshops. A SWOT analysis was applied in order to identify strengths, weaknesses, opportunities and threats of agroforestry concessions as well as strategic actions for its implementation. The interviews allowed to identify 19 incentives, which can be grouped as follows: research and extension services, administrative procedures, infrastructure and basic services, market development and financial mechanisms. The results of the research confirm that there are important differences between the political levels. Institutional stakeholders at both levels (national and regional/local) are more concerned in facilitating the process of access to agroforestry concessions because directly affects the implementation of this instrument. In contrast, the proposed incentives by farmers respond to the current needs and limitations on what they have on their daily basis. Taking into account the growing market in agroforestry products, agroforestry concessions offer strong potential for sustainable development in Peru and other tropical countries. However, as the study shows, implementation depends on the institutional setting, policy environment and social, economic and environmental conditions of farmers. Further studies are necessary to explore similarities and differences for a successful implementation in other parts of Peru and other countries.

**Keywords:** Agroforestry concession, incentives, Peruvian amazon, policy instruments

## The Feminisation of Agriculture in South Asia: An Opportunity for Farmer Collectives?

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Male out-migration from rural communities to urban areas and abroad for better economic opportunities is not a new phenomenon. Nevertheless, only few studies explore how the absence of men affects access to and control over decision-making processes on water, land and agriculture within patriarchal and caste-based societies.

The so-called feminisation of agriculture refers to more than only the demographic rise of women-headed households. While women were previously responsible primarily for reproductive tasks, they now enter new spaces which previously were men's responsibility: farm management, income generating labour and community leadership. As the literature on the feminisation of agriculture has pointed out, this is associated with both new vulnerabilities such as an increased labour burden, and opportunities for women's empowerment in water and land management in small-scale farms.

Moving beyond notions of the "left behind", diverse women's perspectives on their own empowerment within an era of agrarian transformation through male out-migration and climate change are examined. Case studies of villages in Nepal, India and Bangladesh demonstrate how women of different caste, class and age within various household setups experience gendered norms, roles and relations in their community in regard to water access and agricultural practices. Based on findings of the ACIAR-funded project "Improving water use for dry season agriculture by marginal and tenant farmers in the Eastern Gangetic Plains", this presentation will investigate how a collective approach to farming can address gender inequality in water resource and land tenure structures in Bihar and West Bengal in India as well as the Eastern Terai in Nepal.

**Keywords:** Bangladesh, dry-season agriculture, farmer collectives, feminisation of agriculture, gender, India, migration, Nepal, small-scale agriculture, South Asia, water management

## Meta-Analysis of Rural Household Adaptation Strategies to Environmental Change in Sub-Saharan African Drylands

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Drylands encompass approx. 40 % of the global earth surface and arguably constitute one of the world regions that are impacted the most by global environmental and climate change. It is estimated that about one billion people in drylands directly depend on natural resources for their livelihood. These people suffer particularly from worsening environmental conditions and often have few capabilities to compensate for lacking resources or the consequences of extreme weather events.

Local case studies have proven to be an effective instrument to investigate adaptation behaviour of different population groups in the context of environmental and climate change. The knowledge generated by these studies is crucial for the strategic development of climate change adaptation measures, natural resource and migration management on national, regional and international level. However, given context-specific local framework conditions, case study results are rarely directly applicable to bigger regions. Consequently, synthesis methods are needed to generate transferable results that can be incorporated into political processes. A major strength of these methods is the possibility to promote an understanding of underlying processes, causal linkages and patterns while maintaining the descriptive richness of local case studies.

This presentation outlines the approach and preliminary results of a comprehensive meta-analysis of household adaptation strategies in the context of environmental change with a focus on sub-Saharan African drylands. The aim of this study is to identify relevant strategies adopted by rural households to adapt to or cope with different types of environmental change and a variety of factors influencing their behaviour. Particular attention is paid to potential ‘adaptation pathways’ and regional / sub-regional patterns.

This meta-analysis is part of a dissertation project within the framework of MigSoKo, an interdisciplinary junior research group investigating the complex dynamics between environmental change and human migration in the tropics. The analysis outlined above will essentially contribute to a better understanding of the role of migration as environmentally-induced adaptation strategy.

**Keywords:** Adaptation, coping, environmental change, meta-analysis, sub-Saharan Africa

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# Institutions

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1) Central Asia I	527
2) BMEL session	547
3) GIZ session: Scaling Out - Cooperation between Research and Development	557
4) Central Asia II	561

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# Central Asia I

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## Invited Paper

- JIANCHU XU:  
**Mountain Futures: Seeds of Change in the Asian Highlands** 529

## Oral Presentations

- CHRISTIAN BAUER, MICHAEL THIEL, FABIAN LÖW, DORIS KLEIN, CHRISTOPHER CONRAD:  
**Spatio-Temporal Patterns of Land Abandonment in the Lower Region of Amu Darya River** 530

- JOHN LAMERS, BERNHARD TISCHBEIN, MAKSUD BEK-CHANOV:  
**Water in Central Asia: Abundantly Available, Heavily Contested, But Glue to International Collaboration** 531

- ELISABETH BARANOWSKI, NIELS THEVS, ALTYN KHALIL, AZIM BAIBAGYSOV, MARGULAN IKLASOV, SABIR NURTAZIN, VOLKER BECKMANN:  
**Pastoral Farming in the Ili Delta, Kazakhstan, under Decreasing Water Supply: An Economic Assessment** 532

- LARS CASPERSEN, ALINA JOANA GOMBERT, MARTIN HOMMELS, MARKUS DELLER, MARCELI WIKTOR PAWOLKA, JAN SCHLOSSAREK, BERMET DJURUPOVA, KLARA DZHAKYB-BEKOVA, JENS GEBAUER, GULNAZ KASEEVA, RALF KUCHENBUCH, ASYLBEK KULMYRZAEV, DAVLET MAMADJANOV, MARTIN MAURER, RUSTAM NURMATOV, ZBYNEK POLESNY, JÜRGEN PRETZSCH, ZAKIRHODJA SARYMSAKOV, DIETRICH SCHMIDT-VOGT, JAMILA SMANALIEVA, VLADIMIR VERNER, FLORIAN WICHERN, NIELS THEVS, SYLVIA MOENICKES, FLORIAN KUGLER, DIETRICH DARR:  
**Utilizing the Nutritional Potential and Secondary Plant Compounds of Neglected Fruit Trees and Other Plant Species of the Walnut-Fruit Forests in Kyrgyzstan** 533

## Posters

- WELCOME ZIMUTO, JANA MAZANCOVA, TOMAS RATINGER:  
**Optimisation of Cooperative Herb Farmers' Production in Imereti, Georgia** 535



MAJID ROSTAMI, ZAHRA MOVAHEDI, SAMIRA SIAHPOOSH: <b>Effect of Foliar Application of Biofertiliser and Nano-fertilisers on Morpho-Physiological Characteristics of Peppermint (<i>Mentha piperita</i> L.)</b>	536
SHAVKAT KENJABAEV, MUROD SULTANOV, CHRISTIAN BAUER: <b>Assessment of the Land Reclamation Condition Using Environmental Variables in Ellikkala District, Karakalpakistan</b>	537
ELENA KAN, INNA RUDENKO, JENS WUNDERLICH: <b>Communication Strategy for the Conservation of Flood-Plain Forests in the Amudarya River Basin, Uzbekistan</b>	538
AIPERI OTUNCHIEVA, SISIRA WITHANACHCHI, ANGELIKA PLOEGER: <b>Rainwater Harvesting as a Sustainable Alternative for Ensuring Food Security</b>	539
YULIA SHIROKOVA, GAUCHARAY PALUASHOVA, FARKHAD SADIEV, NAILYA SHARAFUTDINOVA: <b>Influence of Biological Preparations on Melioration of Saline Soils: Case Study from Uzbekistan</b>	540
SOUDABEH ALI AHMAD KORORI, ELAHEH MADANI MASHAEI, SEYEDMAHMOUD MONEMIAN: <b>The Consequence of Agroforestry in Genetic Diversity of Oak Forests of West of Iran</b>	541
MASOUD YAZDANPANAH, NOZAR MONFARED, ELHAM BOZORGPANAH: <b>Human Factors in Deployment of Renewable Energy in Iran: The Case of Dairy Farmers</b>	542
MOHAMMAD HOSSEINI, ABDOLLAH MOLLAFILABI: <b>Increasing Water Use Efficiency in Saffron (<i>Crocus sativus</i> L.) Cultivation</b>	543
VIDA VARNASERI GHANDALI, ABBAS NASIRI DEHSORKHI: <b>Foliar Application of Zinc Oxide on Yield of Cowpea under Cutting of Irrigation Conditions</b>	544
NAILYA IBRAGIMOVA, OLEG ESYREV, ADIYA IBRAGIM: <b>Study of Quality Water in Bypass Channel and the Sorbulak Lake (Almaty, Kazakhstan), Used for Irrigation of Agricultural Land</b>	545

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## Mountain Futures: Seeds of Change in the Asian Highlands

JIANCHU XU

*World Agroforestry Centre (ICRAF), China and East Asia Office, China*

Mountains regions provide vital ecosystem services, serve as storehouses for biological and cultural diversity, and are on the frontlines of global change. Yet their role has often been marginalised, and predictions of the future often cast the mountains as areas of increasing poverty and environmental degradation. We propose an alternative narrative which recognises the possibility of a ‘good Anthropocene’, and which realises the potential for mountains to act as testing grounds for adaptations to global problems. This conception of Mountain Futures aims to harness the ingenuity, diversity and wisdom of mountain peoples for positive change.

The Asian Highlands are home to a unique concentration of both biological and cultural diversity which has co-evolved over centuries to produce a range of farming systems adapted to multiple environments and climates. The knowledge embedded in these systems needs to be recalibrated for new challenges such as climate change, and there is thus an urgent need to combine local, traditional knowledge with nonlocal, scientific expertise in order to build adaptive capacity for a new generation.

The Mountain Futures Initiative was launched in 2016 as a means of meeting this challenge. The Initiative aims to realise sustainable visions of the future through the establishment of a multi-stakeholder regional platform aimed at identifying, supporting and scaling up “seeds of change”. “Seeds” are ideas or projects that are currently undeveloped but which have the potential to bring about positive environmental, social, and economic change in mountain regions. Agroforestry can play a key role in bringing about this change through equipping land managers with effective tools to safeguard their livelihoods and environments.

Examples of seeds include: an integrated approach to mining site restoration using agroforestry and fungi to rapidly deliver improvements to soil health and recover ecosystem functions; the revitalisation of traditional ecological calendars to synchronise agricultural activities with phenological cues; wild mushroom domestication in the Mekong region; the development of sustainable urban food systems in mountain areas; smart infrastructure planning to minimise the costs and maximise benefits of road-building.

**Keywords:** Agroforestry, food systems, good anthropocene, mountain futures, seeds for positive change

## Spatio-Temporal Patterns of Land Abandonment in the Lower Region of Amu Darya River

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Since the collapse of the Soviet Union, farmlands in Uzbekistan have been widely abandoned. However, the dependency on agriculture is still high for cash crops, particularly in context of food security and a rapidly growing population. Despite vast research in land degradation, the processes and drivers for abandonment remain hardly understood. Until now, no or little attention was paid to site-specific developments such as abandonment of arable land in irrigation agriculture and abandonment of land that was reclaimed in arid and semi-arid regions. Analysis of time series from Landsat earth observation data are recognised as highly suitable to establish retrospective and current land use changes. We combined multi-annual Landsat data and Random Forest machine learning to classify arable land and to discriminate between used and unused fields for the observation period between 2000 and 2016. The fields classified as “unused” were then subdivided according to their intensity of intra-annual NDVI signal that was used as further proxy to get information on the time at which the field became abandoned. A pixel-based classification was preferred instead an object-based classification to minimise prediction errors on field level. Furthermore, intensity information was used for validating retrospective data for years without field survey information. Overall, the classification of unused land was challenged by the complexity of the crop rotations, long fallow cycles, and the data scarcity. The derived information is concluded to support regional land use planners and decision makers to improve land management and to designate regions for alternative usages such as pastoralism.

**Keywords:** Abandoned farmland, land degradation, land-use change, machine learning

## **Water in Central Asia: Abundantly Available, Heavily Contested, But Glue to International Collaboration**

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Central Asia is not only prominent for its human-made environmental catastrophe of which the Aral Sea crises is probably the most well-known, but not only example. The fashionable opinion that Central Asia as a whole is saddled with a water crises is truthful as well. But the trendy view that the region needs to cope with water scarcity, is however, regardless of how often it is repeated, only marginally supported by facts and figures from the past and present. The five countries in Central Asia, Kazakhstan, Kyrgyzstan, Uzbekistan, Tajikistan and Turkmenistan appear since years among the top per capita water users worldwide, with concurrently very modest to low water use efficiencies in the irrigated agricultural sector that however consumes the bulk of all water resources in the region. And this regardless the indicator analysed. Yet, the fact that the farming communities in e.g. tail end regions regularly face water shortages during cropping periods masks for a larger part the true causes of the water crises. This study unravels the water crises in Central Asia by tackling international and national facets and its relationships. It also addresses options for actions to ease the current water crises by structuring these on national level according to technical, financial and institutional aspects. It is concluded that the water crises in Central Asia clearly has international characteristics and much has been done. Predominating are also domestic facets that can be tackled by the individual countries and farmers. Yet, a collaboration among the countries in Central Asia is highly recommended to be better prepared for the water challenges to come.

**Keywords:** Aral Sea Basin, upstream. downstream, water scarcity

## **Pastoral Farming in the Ili Delta, Kazakhstan, under Decreasing Water Supply: An Economic Assessment**

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The Ili Delta with an extension of 8 000 km<sup>2</sup> is the largest natural delta region of Central Asia. It contains large areas of pastures, which are dominated by *Phragmites australis* reed vegetation. For local population, pastoral farming is one of the most important land use forms and income sources. The pastures are almost entirely dependent on Ili River's runoff. The Ili River is a transboundary river shared by China, upstream, and Kazakhstan, downstream. Due to the expansion of irrigated agriculture, as well as, shortcomings of inter-governmental agreements, the Ili Delta is threatened by water shortages and subsequent pasture degradation.

Against this background we aim to assess these threats from an economic point of view and analysed the economy of the pastoral system in the Ili Delta in its current state and in three scenarios including different assumption on water supply: (I) sufficient water supply (normal situation), (II) decreasing water supply, and (III) significantly decrease of water supply (worst case). Data was collected in 2015 through 35 farm and additional expert interviews. Production parameters were calculated and entered to a cost-benefit analysis, in order to estimate profits of livestock keeping for three scenarios.

Three farm types, family-, medium- and large-scale farms, were identified at a range between subsistence and market orientated commercial production. Beef cattle, 24 000 animals in 2015, dominate livestock throughout the Ili Delta. Interviews revealed a continuous decrease of water flow into the Ili Delta over the last few years. This already resulted in a qualitative and quantitative reduction of pastures at margins of the Delta, where most of villages are located. Big commercial farms produce at the upper stretch of Ili River, whereas villages at the underflow are almost cut off water supply. As adaption strategy in face of pasture degradation, most farmers purchase winter fodder. According to our calculations, this significantly reduces profits of worst case in comparison to normal situation (by 80 or 90 %) for all farm types. We conclude that under further decreasing water supply, especially downstream village population will have to reduce livestock significantly or out migrate from the delta region completely.

**Keywords:** Adaption strategy, cost-benefit analysis, upstream-downstream conflict

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## Utilizing the Nutritional Potential and Secondary Plant Compounds of Neglected Fruit Trees and Other Plant Species of the Walnut-Fruit Forests in Kyrgyzstan

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Forests make important contributions to safeguarding agricultural production, food security and nutrition of rural and urban populations. The walnut-fruit forests in Kyrgyzstan constitute a unique resource in this regard. Simultaneously, they are of global importance as a biodiversity hotspot. However, current patterns of forest management are unsustainable, large parts of the forest are overaged and benefits derived from these forests are unequally distributed among local populations. Walnut (*Juglans regia* L.) kernels have traditionally been used for human diets and constitute an eco-

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nomically important product of these forests. Although the walnut value chain in Kyrgyzstan is of significant economic importance, the level of domestic processing is low and locally manufactured walnut products are of low quality. The SUSWAL-FOOD project (funding code 01DK17016) aims at contributing to the development of nutritious food from neglected and underutilised plant species of the Kyrgyz Walnut forests, thereby improving local food security, promoting sustainable forest management, and increasing local incomes.

Initial analyses have investigated timber growth of walnut trees and quality parameters of respective walnuts from various parts of the forest. Regarding quality parameters, nut dimensions, walnut weight, kernel weight, and rupture force were determined resulting in a classification of the investigated trees. Results show that most trees are old and may therefore be anticipated to display declining walnut yields, underlining the need for forest rejuvenation. Timber and walnut quality varied greatly across the study area. These results will facilitate the selection of superior trees for forest regeneration. Further work in this project aims to analyse the nutritional composition and secondary plant compounds of other selected plant species of the walnut forests and their potential use in new food products; further investigate the morphology, diversity, and plant-soil interaction of these species to determine their biological productivity and to support sustainable management and conservation efforts; and finally examine the socioeconomic and gender-specific impacts of traditional and contemporary utilisation including market chains and cost-benefit assessments at household level.

**Keywords:** Bioeconomy, Central Asia, food security, forest-based rural development, fruit tree, nutrition, value chain

## Optimisation of Cooperative Herb Farmers' Production in Imereti, Georgia

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Agricultural cooperatives play an important role in supporting small agricultural producers in developing countries. This study was carried out in Georgia, Imereti Region to model alternative profit maximisation and crop-land allocation strategies for two cooperative herb farms. 32 farmers from two cooperatives; Dovlati and Kvitiri were interviewed. We simulated 3 scenarios for each cooperative using General Algebraic Modelling System. The GAMS results were used to assess the best crop land allocation strategy with profit and crop land allocation as the key informant variables. The results of the first and second scenarios in both cooperatives recommended farmers to grow only fennel crop while abandoning parsley and coriander herb crops. To offset the one crop allocation recommended in scenarios 1 and 2, the market constraint was introduced in the third scenario. The model results for scenario 3 recommended the farmers to grow fennel and parsley and not to grow coriander for both cooperatives. As such scenario 3 was selected as the suitable optimal profit maximisation alternative for both cooperatives. The shadow prices associated with all the scenarios indicated that the farmers were over utilising land and labour resources. In all the three models there was a slight decrease in profit as we progressed from the first scenario simulation to the third scenario simulation. The model presented both cooperatives with an opportunity to maximise their profit margin if the farmers cooperate both on production and marketing. In conclusion the model can be further developed into a comprehensive sector model and be used by the agricultural ministry of Georgia and the farmers as an instrument for effective farm decision making.

**Keywords:** Cooperative farmers, crop-land allocation strategy, profit maximisation, shadow prices

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## Effect of Foliar Application of Biofertiliser and Nanofertilisers on Morpho-Physiological Characteristics of Peppermint (*Mentha piperita* L.)

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Peppermint (*Mentha piperita* L.) leave extracts are being used widely in pharmaceutical, food and cosmetic industry. Although this plant originally is not native to Iran, its cultivation significantly increased during the last two decades. As the use of chemical fertilisers and their influence on the environment is viewed critically, bio- and nano-fertilisers may become an alternative fertiliser source. In order to evaluate the effect of foliar application of nano- and bio-fertilisers on the morpho-physiological characteristics of peppermint, a completely randomized experiment was conducted with 7 treatments and 3 replications at the research greenhouse of Malayer University in 2015. Treatments were control, foliar application of 3 different nano-fertilisers (aqueous solution of nitrogen, iron and potassium at the rate of 2 g L<sup>-1</sup>) and foliar application of 3 different bio-fertilisers (normal vermiwash, enriched vermiwash (normal vermiwash + aqueous extracts of *Urtica dioica*) and tea compost). After transplantation stems were cut at 3 cm above the soil level and plants received first foliar application when the stem reached 5 cm of height. Foliar application was effectuated by evenly spraying of the solution until the whole plant was wet; spraying was done 4 times at weekly intervals. The results showed a significant positive effect of both nano- and bio-fertilisers on plant height, leaf area, leaf dry weight, total dry weight, relative water content, photosynthesis pigments and the concentration of mineral nutrients. The lowest amount of leaf dry weight (1.73 g pot<sup>-1</sup>) was observed for the control. The application of nitrogen nano-fertiliser increased leaf dry weight by 165%. The lowest plant height (12 cm) was recorded for the control, whereas the highest plant height (28.8 cm) was found for the nitrogen nano-fertiliser treatment followed by the enriched vermiwash (20.4 cm). In all treatments the chlorophyll *a* content was higher than found for the control, but the application of enriched vermiwash resulted in the highest amount of chlorophyll *a* (2.4 mg g<sup>-1</sup> FW). The highest amount of soluble protein (1.53 mg g<sup>-1</sup> FW) was related to enriched vermiwash but the lowest soluble protein content (1.05 mg g<sup>-1</sup> FW) was observed in tea compost treatment. In general, nitrogen nano-fertiliser and enriched vermiwash had the highest positive effects on the studied traits and were the best fertilisers among nano-fertilisers and bio-fertilisers, respectively. It is therefore recommendable to use enriched vermiwash or nitrogen nano-fertiliser for increasing the yield and quality of peppermint.

**Keywords:** Compost, crop nutrition, medicinal plants, nano-fertiliser, vermiwash

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## Assessment of the Land Reclamation Condition Using Environmental Variables in Ellikkala District, Karakalpakistan

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Adverse amelioration condition of irrigated lands is an increasing problem to maintain sustainable agricultural production in the Central Asian countries, especially in lowlands of the Amudarya and Syrdarya rivers. Establishing systems for analysis of land reclamation condition using environmental information which is difficult or expensive to collect, update, or upgrade, even if valid scientifically, will have limited utility when used for large, complex environments or when used for continuous monitoring. However, combined assessment of available variables is lacking in Uzbekistan in particular and in Central Asia in whole. How can the available data from different organisations be integrated? What are the relationships amongst the factors? These are major issues which are not easily resolved. It is, however, only through an integrated, multi-level, approach that both the land and water management and the existing interactions amongst the individual components of the landscape can be evaluated. In response to these problems, main goal of this study is to explore and review existing assessment methods used in Uzbekistan to assess and map land reclamation condition and find out environmentally sensitive areas, on which further land improvement measures can be taken.

The GIS software, with available soil, vegetation, hydrological and infrastructure data was successfully employed to create thematic layers and to assess land reclamation condition in Ellikkala district, Karakalpakistan. Delineation of environmentally sensitive areas of study area was performed based on thematic layers. Created method in a GIS environment simplifies data handling, provides ease of access to the information acquired and its timely updating, and enhances interpretation by facilitating cross data analysis procedures and the application of sophisticated classifications. The approach also allows identifying and understanding the factors that combine and accelerate land degradation in order to adequately manage the land and its resources.

By noticing the evaluation of environmental factors, the soil (texture), land condition (groundwater table) and water availability (distance to the irrigation systems) have the intensive effect on land reclamation condition throughout the study region. A GIS tool has the potential to generate maps that can be used in specific land management improvement programs.

**Keywords:** GIS, Karakalpakistan, land reclamation condition, remote sensing

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## Communication Strategy for the Conservation of Flood-Plain Forests in the Amudarya River Basin, Uzbekistan

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Once widely spread across Central Asia, nowadays the unique tugai flood-plain forests in the lower reaches of the Amudarya river in Uzbekistan are under desperate pressure due to reduced natural flood regime, intensive land use for irrigated agriculture and overexploitation of forest resources. The establishment of the Lower Amudarya state biosphere reserve (LABR) in 2011 demonstrated the governmental commitment to preserve the biodiversity of degrading tugai habitats through a new management model for protected areas and sustainable use of natural resources. Biosphere reserves are worldwide model regions in which sustainable farming systems are tested and disseminated in accordance with the needs of nature and of humans. In addition to the protection of natural areas biosphere reserves serve to integrate the local population through environmental education and promotion of sustainable and ecological farming systems. For the LABR administration all the above turned to be new tasks, for which there still remains an ample room to enhance scope and effectiveness. Furthermore, among stakeholders, there is still a limited understanding of both biosphere reserve concepts, and the urgent need for conservation of tugai ecosystems vital for local communities, as well to humanity on a regional and global level. This calls for creating a common understanding about the importance of tugai ecosystems and elaboration of communication strategies for their conservation, which should be inter-linked with almost all activities of management of a biosphere reserve. The suggested communication strategy is based on the following goals: a) use the protected tugai floodplains of the Amudarya river basin and its surrounding areas for research, monitoring, education and training; b) improve education for sustainable development, public awareness and involvement of local people in various activities, generally aiming at the conservation of the unique and globally significant tugai habitat. The present paper is based on NGO-led activities in LABR within the on-going BMZ-funded project “Ecosystem based land and forest management of the tugai habitats of Amudarya river for improving livelihood of local communities and as adaptation strategy to climate change”, which is implemented in Uzbekistan in partnership with the Michael Succow Foundation for the Protection of Nature.

**Keywords:** Amudarya river basin, biosphere reserve, Central Asia, communication, tugai floodplain forest

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## Rainwater Harvesting as a Sustainable Alternative for Ensuring Food Security

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Rainwater harvesting (RWH) has been used since ancient times and started gaining popularity recently. As simple, cost effective and sustainable alternative for securing food, RWH offers stability in terms of water availability for agricultural output for smallholder farmers in arid and semi-arid areas. Although trivial forms of RWH exist in such areas, efficiency of water use might be doubtful. To be precise, poor water maintaining capacity, increased level of evaporation, absence of calculations of local precipitation levels and actual annual need for irrigation water weakens efficient use of this precious natural resource. Taking into account this assumption, the article seeks practical solutions for food security in the absence of water system infrastructure in rural areas. Our hypothesis states that even with annual precipitation less than 300 mm, it is possible to ensure and maintain rainfed agriculture. This work serves as a continuation of the previous research completed in April 2015 on kitchen gardens in this area. The theory and practice-based training sessions were provided for the farmers (n=15) in the Shybran village of Batken province in southern Kyrgyzstan, and took place at the end of dry and beginning of rainy season (August). Within this framework, farmers were informed about the chances to increase water supply, improve water use efficiency and employment of appropriate crops in terms of local climatic conditions. In addition, the farmers were given financial support to construct RWH structures. These RWH structures will increase water use efficiency, and their wider dissemination among rural farmers in southern Kyrgyzstan, will insure water sustainability, increase reliance on self-grown food, and eventually decrease youth migration from rural areas.

**Keywords:** Arid and semi-arid areas, climate change, local initiatives, water efficiency, water sustainability

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## **Influence of Biological Preparations on Melioration of Saline Soils: Case Study from Uzbekistan**

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Lowland and desert areas of Uzbekistan are prone to soil salinisation, which has a seasonal character and increases from spring to autumn. This phenomenon affects soil fertility and land productivity. This paper presents a study on an application of locally produced biological and biochemical preparations with the purpose to assess their effectiveness and environmental safety as a mean for the melioration of saline soils of Uzbekistan. Experiments were carried out with different preparations developed by Uzbek scientific institutions. Two biological preparations (Rizkom-1 and Trichodermin) applied through watering of cotton seeds before sowing should activate microbiological processes in saline soils. The Rizkom-1 is developed by the Institute of Microbiology of the Science Academy of Uzbekistan based on algae called chlorella, whereas Trichodermin, with the active ingredient trichoderma – a naturally occurring mycopathogenic fungus – is produced by the Uzbek Research Institute of Plant Protection. Further, we tested locally produced biochemical preparation “Biosolvent” developed by the Institute of Bioorganic Chemistry of the Science Academy of Uzbekistan and its effect on leaching of salt from the soil. In all the experiments we checked moisture, salinity and chemical composition of the soil before and after treatment. The results show that preparations maintain a higher moisture content in the soil which can lead to water savings during irrigation. This concerns in particular the application of Rizkom-1. Additionally, leaching with the upfront spraying of the soil with 11 % solution of the preparation “Biosolvent” and subsequent supply of 2000 m<sup>3</sup> ha<sup>-1</sup> of water, toxic ions (chlorine, sulfates and sodium) are more washed out as the control. At the same time, there was no negative influence of “Biosolvent” in the form of increased leaching of nutrients NPK from the soil.

**Keywords:** Biological preparations, chemical composition of soils, leaching, melioration, saline soils, spraying of soil, watering of cotton seeds

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## The Consequence of Agroforestry in Genetic Diversity of Oak Forests of West of Iran

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In the past decade, oak mortality in the Zagros oak forests (western Iran) have been reported repeatedly. Many hypotheses for the decline of the Persian Oak (*Quercus persica*) have been presented, amongst it its genetic extinction. Agroforestry systems are one of the prevalent management systems in these natural forests. The goal of this paper was to investigate the impact of agroforestry on the natural oak forests of Ilam province, especially with regard to the intraspecies genetic diversity; as this was identified as a possible cause of oak decline. The study sites were located in the Zagros region, Ilam province, West Iran, bordering Iraq. Three study sites were chosen randomly in similar ecological conditions, to provide an assessment of the effect of the agroforestry management system on the genetic diversity of Oak trees. The first site was located in a 22-year old protected forest area (control site), the second site was located in a forest under moderate agroforestry management and the third one was located in an area under agroforestry management only. In each site, leaf samples were taken from 15 stands. Additionally, in the surrounding area of each site, leaves from 25 individual stands were sampled as a control in order to consider genetic diversity. Therefore, in total 70 individual stands were selected for molecular investigation. The genetic diversity of the samples was evaluated using microsatellite molecular markers (SSR method). According to the results of molecular studies, the minimum number of the polymorphic loci (24) was observed for the third site (highest rate of agroforestry), and the maximum number of the polymorphic loci (27) was observed for the first site (undisturbed protected area). Moreover, site 2 showed 26 polymorphic loci. The results also revealed a high intra-species diversity (31 polymorphic loci in total). Therefore, it can be concluded that an inappropriate agroforestry management in these natural oak forests might lead to a strong decrease of the intra-species diversity.

**Keywords:** Genetic diversity, intra-species diversity, Persian oak, Zagros

## **Human Factors in Deployment of Renewable Energy in Iran: The Case of Dairy Farmers**

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An increasing global energy demand, concerns about energy security such as availability of fossil-fuel resources and dependency on these, anthropogenic emissions of greenhouse gases and environmental degradation caused by energy generation from fossil fuels, stimulated debate on future efficacy of fossil fuel. In this situation, renewable energies sources (RES) can be one of the options to satisfy energy demand with low carbon energy generation. The government of Iran is recognising the potentials of RES and announced the plan to deploy 2 GW of RES capacity between the years 2010 – 2015. However, scientific evidence shows that public acceptance is an important issue for the deployment of such policy. The aim of this study is to provide much-needed empirical data about dairy farmers' attitude and willingness to use renewable energy instead of fossil fuel energy at their farms. This will provide a knowledge base for the development of public policy measures that ultimately aim to increase growing renewable energy production among Iranian dairy farmers. For this purpose we apply a well-established social-psychological model, the Theory of Planned Behaviour, to identify the psychosocial factors that influence attitudes of dairy farmers towards renewable energy. The empirical data collection part includes a cross-sectional survey among dairy farmers in the Khokeloh and Boerahmad Province in the southern Iran. The data were collected with the help of personal interviews, which were based on a questionnaire specially designed for this survey. The reliability and validity of the instruments were examined and approved

Structural equation modelling showed that moral norms, attitudes and perceived behavioural control are significant factors influencing willingness to use of renewable energy, while subjective norms and self-identity do not play a significant role. These variables can predict nearly 57 % variance in dairy farmers' willingness. The findings yield public policy implications for renewable energy use among dairy farmers.

**Keywords:** Dairy farmers, Iran, psychological factor, renewable energy

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## Increasing Water Use Efficiency in Saffron (*Crocus sativus* L.) Cultivation

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An experiment was conducted at the Gonabad Research Station of Agriculture and Natural Resources, Iran to demonstrate the effects of moisture stress on saffron yield and quality in 2012 and 2013. The statistical design was a randomised complete block design with five treatments and four replicates. The treatments were: irrigation till 70 % field capacity (FC), 60 % FC, 50 % FC, first control (three irrigations), and second control (three irrigations + one in mid summer). Quantitative measurements were number of flowers, fresh weight of flowers, dry stigma, number of corms and corm weights, as well as at the end of the experiment amount of corm covering, and dry weight of leaves. Quality measurements included amount of picrocrocin, crocin and safranal. Combined analysis for two years showed no significant effects on quantitative characteristics but high significant effects on quality characteristics. By reducing irrigation to 50 % FC quality factors increased and showed positive effects of moisture stress on saffron quality. However, there was a trend of decreasing quantity characteristics because of a reduction of soil moisture content. For increasing saffron stigma yield three irrigations + one irrigation in mid summer is optimum. For increasing the amount of picrocrocin, crocin and safranal a moisture stress is desirable. Actually, efforts are necessary to increase water use efficiency (WUE) in saffron with respect to the actual used 3000 m<sup>3</sup> water ha<sup>-1</sup> for an economical yield. Such a WUE optimisation is especially necessary because of recent drought years in the main areas of saffron cultivation in the great Khorasan. The results of this experiment showed that moisture stress as much as 60 % FC can be recommended for both saffron quantity and quality.

**Keywords:** Quality factors, saffron covering, stigma



## Foliar Application of Zinc Oxide on Yield of Cowpea under Cutting of Irrigation Conditions

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Drought stress is one of the most adverse factors of plants growth and productivity. Proper nutrition availability under stress conditions could partly help the plant to tolerate different stresses. Zinc plays a key role in the synthesis of proteins, DNA, and RNA. In order to investigate effect of foliar application of Zinc oxide in common and nanoparticles form on yield and yield components of cowpea (*Vigna sinensis* L.) under drought stress conditions, an experiment was carried out as a split plot complete randomised block design with three replications in a field located in Shooshtar city in Iran, during the growing season of 2014–2015. Water stress at three levels (control, cutting of irrigation at 50 % flowering, and cutting at 50 % pod setting stages) were assigned as main plots and zinc oxide foliar application at five levels (control, 5 and 10 g l<sup>-1</sup> nano sized zinc oxide, and 5 and 10 g l<sup>-1</sup> non-nano-scale zinc oxide) were randomised in sub-plots. The results suggested that the drought stress at flowering and podding stages decreased the 100-seed weight by 36 % and 21 % in comparison to control treatment, respectively. The maximum effects of Zinc on increasing traits was found by foliar application of 10 g l<sup>-1</sup> nano zinc oxide, 10 g l<sup>-1</sup> zinc oxide, 5 g l<sup>-1</sup> nano zinc oxide and 5 g l<sup>-1</sup> zinc oxide, respectively. The results showed that foliar application of 10 g l<sup>-1</sup> nano zinc oxide in the control and for the drought stress at flowering and podding stage treatments, increased the grain yield by 64 %, 57 % and 37 % in comparison to the control without foliar application, respectively. Positive effects of application of nano-scale zinc oxide particles on yield and yield components of cowpea was higher as those of micro-particles zinc oxide, and can reduce stress effects.

**Keywords:** 100-seed weight, legume, nano particles, water deficit stress

## Study of Quality Water in Bypass Channel and the Sorbulak Lake (Almaty, Kazakhstan), Used for Irrigation of Agricultural Land

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This study undertakes researches of sewage water quality indicators after purification: in the bypass channel and in the lake-collector Sorbulak which water is used for irrigation of field and technical cultures.

Determination of phosphate, sulphates and nitrites shows that the level of these biogenous elements in Sorbulak lake has been twofold reduced in comparison with the channel water:  $10.04 \pm 0.07 \text{ mg ml}^{-1}$  /  $22.7 \pm 0.2 \text{ mg ml}^{-1}$ ,  $405.2 \pm 0.05 \text{ mg ml}^{-1}$  /  $987.6 \pm 0.60 \text{ mg ml}^{-1}$  and  $22.5 \pm 0.08 \text{ mg ml}^{-1}$  /  $34.6 \pm 0.05 \text{ mg ml}^{-1}$ , respectively.  $\text{NO}_3^-$  - anion in channel water and in Sorbulak were lower than  $23 \text{ mg l}^{-1}$ , and the content of total nitrogen lies within  $30\text{--}39 \text{ mg l}^{-1}$ .

Sorbulak lake showed a reduced concentration of phenol  $2.02 \pm 0.08 \text{ mg l}^{-1}$ , aluminum  $0.12 \pm 0.01 \text{ mg l}^{-1}$ , and lead  $3.66 \pm 0.06 \text{ mg l}^{-1}$ , compared to the bypass channel, but phenol and lead concentration were still higher than allowed. Moreover, reduction of surfactants (cation, anion) was observed in Lake Sorbulak, but the concentration of neon was practically the same in the channel as in the collector.

The comparative analysis of algological biodiversity identified that the bypass channel water contained more generic diversity (9 genus) as presented by Chlorophyta, and opposite to the Sorbulak lake contained also Chromophyta (7 genus) and Cyanophyceae. Increase of biodiversity of this last group of microalgae can be the reason of inorganic phosphorus and nitrogen absorption and as a result of biomass collection. That is why irrigation water containing these microalgae can stimulate growth of agricultural crops.

Thus, the channel for discharge of sewage water can be considered as an independent purification ecosystem, as the water passing through it continues to purify as a result of diverse form of lives in it. Finally, maximal purification is reached in the lake. However, Sorbulak lake water doesn't correspond to the quality levels for heavy metals and phenols.

**Keywords:** Algae, biogenous element, lake-collector Sorbulak, waste water



# BMEL session

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## Oral Presentations

- SILVIA DIETZ, HANNS-CHRISTOPH EIDEN:  
**Diversified Agriculture for a Balanced Nutrition in Sub-Saharan Africa – Projects Supported by the Federal Ministry of Food and Agriculture, BMEL** 548
- JOCHEN DÜRR:  
**How to Make Nutrition-Sensitive Agriculture Work? Experiences of the NutriHAF Project in SW-Ethiopia** 549
- ERIK ENGEL, HEIDE HOFFMANN, KARIN FIEGE, DOREEN SPARBORTH, MAXIMILIAN BAUMANN, NICOLE PAGANINI, ANJA SCHELCHEN, SAMUEL QUIVE, ABDULRAZAK KARRIEM, DANIEL TEVERA, CHRIS D’AIUTO, SUREN SEWCHURAN, IVO CUMBANA, LUISA MUTISSE CHICAMISSE, ANTONIO PAULO, ERIK DOLCH, MATTHIAS SCHMIDT, KRISTINA BACKHAUS, FILOMENA DOS ANJOS:  
**Urban Agriculture in Mozambique and South Africa. First Evidence from a Complex Research Project** 550
- ETTI WINTER, HARTMUT STÜTZEL, JOHANNES HADERSDORFER:  
**FOSEZA - Food Security in Rural Zambia: Integrating Traditional Fruit and Vegetable Crops in Smallholder Agroforestry Systems** 552
- MARINA GEBERT, DAUD KASSAM, JOSHUA VALETA, DENNIS CHINKHATA, ZIONE KALUMIKIZA, VINCENT MLOTHA, SIFO MOFOLO, BERND UEBERSCHÄR:  
**Improving Community Health-Nutrition Linkages through Solar Energy Based Fish and Crop Integrated Value Chains** 553
- MATIN QAIM, ANDREA FONGAR, THEDA GÖDECKE, LISA JÄCKERING, SYLVESTER OGUTU, MEIKE WOLLNI:  
**Improving Agricultural Extension to Promote Nutrition-Sensitive Innovation: Insights from a Randomised Experiment in Kenya** 555
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## **Diversified Agriculture for a Balanced Nutrition in Sub-Saharan Africa – Projects Supported by the Federal Ministry of Food and Agriculture, BMEL**

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Focus on Nutrition – Research funding of German-African Consortia

With the funding instrument “Research Cooperation for Global Food Security and Nutrition” the Federal Ministry of Food and Agriculture (BMEL) strengthens the contribution of Germany’s agricultural and nutritional research to the development of an efficient food system in partner countries, by building long-term partnerships between agricultural and nutritional research institutions in Germany, Africa and Southeast Asia.

Two calls for proposals have been published since 2013 focusing on diversified agriculture for nutrition-sensitive food production and on improved processing of local food to reduce seasonal food insecurity as well as food and nutrient losses. In this context, twelve consortium projects will be funded by the end of 2017.

Funding agency is BLE.

The BMEL-Session (6B) at the Tropentag 2017 presents a variety of the consortia and their projects funded within the frame of the first call on “Diversified Agriculture for a Balanced Nutrition”:

1. Diversifying agriculture for balanced nutrition through fruits and vegetables in multi-storey cropping systems (NutriHAF), coordinator: The Center for Development Research (ZEF).
2. Urban farming in Southern Africa – improved food safety and income options for urban disadvantaged communities (UFISAMO), coordinator: Humboldt University of Berlin (HU Berlin).
3. Food Security in rural Zambia (FOSEZA): Integrating Traditional Fruit and Vegetable Crops in Smallholder Agroforestry Systems, coordinator: Leibniz Universität Hannover.
4. Improving Community Health-Nutrition Linkages through Solar Energy Based Fish and Crop Integrated Value Chains (*Ich liebe Fisch*), coordinator: Fraunhofer Research Institution for Marine Biotechnology and Cell Technology.
5. Agriculture and Dietary Diversity in Africa (ADDA), coordinator: Georg-August-Universität Göttingen.

**Keywords:** Climate change, diversification, nutrition-sensitive agriculture, research cooperation, sub-Saharan Africa

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## How to Make Nutrition-Sensitive Agriculture Work? Experiences of the NutriHAF Project in SW-Ethiopia

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NutriHAF as a research and capacity building project in the framework of the “Research Cooperation for Global Food Security and Nutrition”, funded by the BMEL, aims at increasing nutrition security by integrating vegetables into multi-storey cropping systems in a biodiversity hotspot of SW-Ethiopia. To achieve this goal, the project creates knowledge about appropriate vegetables and adoption strategies and transfers knowledge to farmers and decision makers about nutritional values, production and post-harvest handling of vegetables. So far, the project showed some interesting results, but also faced some constraints on different levels and dimensions. The main constraint at the beginning was the reluctance of farmers to introduce unknown crops (mainly leafy vegetables) in shaded areas. Another constraint is that female farmers, the main vegetable cultivators, face a high workload. Also, the existing extension services are not specialised in horticulture production, and even if there is official political support to nutrition-sensitive agriculture, this has not been translated yet into concrete actions on the local level. The NutriHAF project responded to these constraints by establishing demonstration plots in shaded and open spaces, by assisting the planting of the vegetables, by giving advice to farmers and extension workers, by organising policy round table discussions and by developing recipes and making cooking demonstrations. The latter turned out to be a key factor for the raising interest of farmers (as consumers) of the newly introduced crops as their good taste convinced them. A major success was that they produced, stored, shared and demanded seeds for the next growing season. If this interest continues to grow, value chains of nutritious leafy vegetables are expected to emerge in the region. For this to happen, the NutriHAF project will continue to generate knowledge and build capacities, give gender trainings, assist market development, create awareness of stakeholders and search for political support. But the strongest driver to make nutrition-sensitive agriculture work seems to be the interest of farmers for tasty food as well as for new cash crop opportunities.

**Keywords:** Ethiopia, leafy vegetables, multi-storey cropping systems, nutrition-sensitive agriculture, research cooperation

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## Urban Agriculture in Mozambique and South Africa. First Evidence from a Complex Research Project

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Sub-Saharan Africa is the most rapidly urbanized region in the world, especially in informal areas. In the course of accelerated urbanisation processes in the global south and the increasing need for sustainable urban planning, urban agriculture has come into focus of scientific research. It has been a popular response to growth dynamics and food crisis in many countries over many centuries.

The research project UFiSAMo is implemented with BMEL funding from 2016 – 2019 by universities in Berlin, Maputo and Cape Town as well as by a private research institution, an NGO and a government organisation. It investigates whether and how urban agriculture can contribute to improving urban food and nutrition security as well as income, especially for disadvantaged communities.

We approach urban agriculture by analysing

- value chains of urban agricultural and consumption habits of urbanites;
- risks and benefits associated with plant and livestock production and good agricultural practices;
- organisational structures;
- most successful communication channels for information sharing from farmer to policy level.

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Action-oriented research ensures that results are directly shared and discussed with farmers and implementing partners. The creation of a research network focusing on urban agriculture and flanked by the development of modules for universities as well as by policy dialogues serve to sustain the results after project funding has ended.

Urban agriculture in Maputo and Cape Town shows distinct characteristics in the ways urban farmers produce, consume and/or market their products. These characteristics entail different benefits and risks for producers and different challenges for researchers.

An overview of the approach as well as of first results and challenges in this complex research project shall be presented:

- value chains for urban agricultural products and challenges in the two cities
- existing challenges and good practices in urban agricultural production in Maputo and Cape Town including product quality
- participatory certification schemes for Cape Town
- existing information dissemination channels and challenges
- challenges in managing such a research project.

At the end, I will indicate more detailed (verbal or poster) presentations of specific components during other Tropentag sessions.

**Keywords:** Dissemination and information, food and nutrition security, good agricultural practices (GAP), income generation, Mozambique, participatory guarantee system (PGS), South Africa, urban agriculture, value chains



## FOSEZA - Food Security in Rural Zambia: Integrating Traditional Fruit and Vegetable Crops in Smallholder Agroforestry Systems

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The FOSEZA project addresses the extreme malnutrition observed in the northern regions of Zambia. The project is going to develop sustainable diets through diversifying the farming system currently dominated by cassava and maize and characterised by significant nitrogen deficiencies. Target crops for diversification are traditional fruit trees and vegetables, such as Masuku (*Uapaca kirkiana*), Intungulu (*Aframomum africanum*), Wild Orange (*Citrus sinensis*), Bambara nut (*Vigna subterranea*), African eggplant (*Solanum aethiopicum*) and Amaranth (*Amaranthus* sp.). It will also be tested if the designed agroforestry system can be combined with small scale fish farming and insect production to increase protein availability. Fish farming is particularly suited for the wetland regions in Zambia; however, current productivity is quite low and the entire production chain needs to be considered to improve the system. The designed farming system will be implemented in a remote village by considering the linkages to input markets and extension services. We look at food security from a gender and community perspective. Developed participatory education tools, agricultural demonstration fields, as well as a community managed tree nursery are aiming to disseminate the knowledge necessary to improving nutrition quality and food distribution within households. Looking at the options for “future agriculture”, particularly the consideration of natural resource depletion and associated environmental costs have changed the beliefs about what agricultural systems will prove to be the most efficient in the long run. Recent concepts like “sustainable intensification”, “water-smart agriculture”, and “wildlife-friendly farming” all address the issues of planetary boundaries and place their emphasis on gender related, smallholder and community oriented strategies. Diversified farming systems managed through an ecosystem approach at the landscape level are believed to increase yields with low external inputs and minimum environmental impact, which will consequently strengthen local food sovereignty. However more sound case studies are needed to test the assumptions and derive options for upscaling. FOSEZA shall contribute to this research gap through a transdisciplinary and interdisciplinary approach. By combining on-station research and participatory field research the project also supports the development of networks between identified action groups.

**Keywords:** Agricultural diversification, food sovereignty, nutrition quality

## Improving Community Health-Nutrition Linkages through Solar Energy Based Fish and Crop Integrated Value Chains

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More than 2 billion people worldwide suffer from macro- and micronutrient deficiencies, specifically in developing countries. Fish is rich in essential fatty acids, contains healthy proteins and many other nutrients that do not occur in such quantity and diversity either in cereals, other crops or in meat. The project “*Ich Liebe Fisch*” focuses on research and linking of several aspects along the value chain of sustainable aquaculture of the endemic fish species *Oreochromis karongae* (“*Chambo*”), a high quality protein source for improving human nutrition in Malawi.

Through the project, the wider implementation of integrated agriculture-aquaculture (IAA) systems will be promoted as an efficient, sustainable and ecological alternative for production of healthy and diversified foods. IAA systems combine fish farming with growing of crops in a synergistic approach. Surface areas in fish ponds or dykes will be used to grow crops, making use of the nutrients produced from the fish. Compared to land-based production of crops, this aquaponics-like approach saves water for irrigation and reduces the evaporation of the ponds. The major input of organic matter comes from fish feed, which is being assimilated into fish protein and, through the faeces of the fish, into highly bioavailable organic fertilisers. These systems will allow enhanced productivity and, eventually, improve nutritional and socio-economic benefits to smallholder fish farmers in the project areas.

Specifically, the project approach is to (a) enhance the production of endemic fish species through breeding and hybridisation, (b) establish a solar powered hatchery and optimise rearing protocols of *O. karongae*, in order to improve the sustainable

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supply of fingerlings for ongrowing farms, (c) integrate nutrient fluxes between animal and crop production, (d) train local communities and smallholder farmers, thus ensuring capacity development in IAA and its benefits, (e) monitor changes in health status and food habits of local families and especially children and elderly people after project implementation, (f) facilitate establishment of a community agriculture-nutrition-health linkage innovation platform and networking with relevant institutions to safeguard sustainability beyond the project life cycle.

**Keywords:** Capacity development, farmers, fish, health, integrated agriculture- aquaculture, solar-powered aquaculture, vegetables

## Improving Agricultural Extension to Promote Nutrition-Sensitive Innovation: Insights from a Randomised Experiment in Kenya

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There is widespread consensus that the small farm sector is a key entry point for improving nutrition in sub-Saharan Africa. Smallholder farmers are not only producing most of the food in Africa, they are also the group that is most affected by food insecurity and undernutrition. Smallholder agriculture needs to be made more nutrition-sensitive, which requires innovation in various dimensions, including better technology, enhanced production patterns, improved agricultural training, and better market access. As is well known, nutrition improvements also require greater awareness and knowledge about healthy foods and dietary practices. What is less understood is how to successfully induce nutrition-sensitive innovation and related behavioural change among smallholder farm households. We analyse the role of agricultural extension services in this connection.

We hypothesise that improved agricultural extension can play an important role for better nutrition. In addition to providing agricultural training, extension officers could provide relevant nutrition education to foster awareness and promote the adoption of technologies and practices that can help to improve dietary quality and micronutrient intake. Such a combination of agricultural and nutrition training has never been tested rigorously. In addition, extension officers could also facilitate market linkages. We evaluate the effectiveness of improved agricultural extension services through a randomised controlled trial (RCT) with farm households in western Kenya. The RCT was carried out and completed in 2016. Different experimental treatments were designed where agricultural training as a standalone approach is compared with alternative approaches that also include nutrition training and market linkage elements.

Data from the baseline (late 2015) and follow-up survey (late 2016) are used to statistically evaluate impacts of the different extension approaches on the adoption of particular technologies (e.g., biofortified beans, improved chicken), household dietary practices, and other relevant variables. Results suggest that the combination of agricultural training with nutrition training is particularly promising. The findings can help to improve the design and effectiveness of extension approaches towards more nutrition-sensitive smallholder systems.

**Keywords:** Extension effectiveness, Kenya, smallholders

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# GIZ session: Scaling Out - Cooperation between Research and Development

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## Oral Presentations

- ANDREA WILHELMI-SOMÉ, MARC BERNARD:  
**Put Agricultural Research into Use to Accelerate the Impact on Income and Productivity for Farmers (Example Benin)** 558
- MARC BERNARD:  
**Innovations Don't Fly – Engaging Young Professionals as Service Providers to Accelerate Adoption and Impact at Large Scale** 559
- CHRISTINA KETTER, TILAHUN AMEDE:  
**Enhancing Resilience of Communities in Pastoral and Agro-Pastoral Systems by Using Water-Spreading Weirs as a Rain-water Management Strategy (Example Ethiopia)** 560
-

## **Put Agricultural Research into Use to Accelerate the Impact on Income and Productivity for Farmers (Example Benin)**

ANDREA WILHELMI-SOMÉ<sup>1</sup>, MARC BERNARD<sup>2</sup>

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The linkage of results delivered by research institutes of tropical agriculture to the implementation activities of development agencies in order to address development goals such as food security more efficiently is getting closer. In Benin, the GIZ programme “Green Innovation Centre for Agriculture and Food Sector (GIAE)” selected innovations which were developed and validated by AfricaRice, a leading pan-African rice research organisation, and its national partners. The innovations include the ASI Thresher, GEM parboiling, mechanical weeders, enhanced power tiller, reaper harvester, transplanter, manual seeder, rice milling unit and rice husk briquetting machine amongst others.

Furthermore, the cultivation of the new rice variety ORILUX 6 bred by AfricaRice, is also successfully promoted by GIAE as this variety has a high consumer oriented quality like the flavor, is drought resistant, increases yield and has high breaking resistance during processing. The implementation and scaling out of those innovations is contributing to all five general objectives defined by GIAE such as increasing rice productivity and farmers’ income, enhancing quality and adding value to rice and rice by-products.

**Keywords:** Benin, cooperation, innovations, rice

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## **Innovations Don't Fly – Engaging Young Professionals as Service Providers to Accelerate Adoption and Impact at Large Scale**

MARC BERNARD

*Africa Rice Center (AfricaRice), Knowledge Management Unit, Benin*

There are no silver bullets in agricultural development, nor have merely participative approaches of the past 30 years proven to provide sustainable diffusion of innovations. The Africa Rice Center has developed a range of scalable technologies, but their implementation remains a challenge and research cannot sufficiently impact people's realities.

Therefore, the Green Innovation Center at AfricaRice in Benin develops service packages to promote promising technologies and to contribute to business development. So to speak it is acting as a "marketing unit" for research products of AfricaRice and national centres. To achieve impact at scale the unit operates on a franchising model. Local institutions and graduates from agricultural colleges and universities are engaged to provide a range of networking, innovation support and business development services in response to the diverse needs expressed by producers and processors. Costing of services is based on the prices of the local economy. Service providers are paid upon delivery using mobile money technology. An internet platform assures monitoring of the innovation process in near real time and to provide feedback to research.

The centre has established a network of 500 service providers covering one third of the country. It is currently assisting 6000 producers directly and is reaching out to 50,000 in 173 villages.

The success of the approach raises structural questions. Do we need a permanent "marketing unit" between research and development organisations to make innovations fly? What would be an appropriate institutional setting in order to meet the diverse demands of end users?

**Keywords:** Benin, cooperation, innovations, rice



## Enhancing Resilience of Communities in Pastoral and Agro-Pastoral Systems by Using Water-Spreading Weirs as a Rainwater Management Strategy (Example Ethiopia)

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Spate irrigation can be abrupt and difficult to regulate. GIZ is looking for a sustainable strategy to rehabilitate degraded, drought-prone landscapes and to maximise the benefits of spate irrigation while reducing its potentially negative consequences on downstream dwellers. Water-spreading weirs (WSWs) were introduced as holistic watershed management approach. Constructed in valley bottoms at the foot of the slopes of mountainous landscapes, WSWs are designed to suit the location – specific requirements of geographical conditions at each site to capture, store and convert run-off water from both erratic rainfall and heavy floods from the highlands. WSWs reduce flow velocity, increase sedimentation of the fertile soil and boost infiltration of water up- and downstream, – how to enhance crop and fodder production on the rehabilitated sites is one of the challenges of the project.

The International Crop Research Institute for Semiarid Tropics (ICRISAT) and its partners have tested some newly developed crop and fodder production options, employing management strategies to stabilise their production and their adaptation to climate variability. Together with farmers, the project assessed, mapped and digitalized soil water-holding capacity (SWHC). This information was then linked to optimal crop and fodder options according to the fertility status of each plot. By assigning targeted crop types to the different plots it was possible to produce about 190 tons of fodder. Grain yield increments of at least 130 % and 200 % were obtained for the cereals and grain legumes respectively. These positive increases are expected to be even higher in the longer term. Water-spreading weirs were also found to be effective at filling up gullies with sediment which enabled the surrounding area to recover its function as pasture or crop land. At the time of writing, GIZ, ICRISAT and their partners are scaling up innovations to neighbouring districts using participatory approaches, as well as working with the Federal Government of Ethiopia to institutionalise proven approaches.

Besides benefiting the agro-pastoral and pastoral communities, both GIZ and ICRISAT have benefited from the strong partnership. By investing in WSWs and creating linkages with institutions in Afar, GIZ has opened-up an opportunity for ICRISAT to test its drought resistant crops and management practices at farm and landscapes scales. On the other hand, ICRISAT has assisted GIZ to convert investment in physical structures to productive use, validating the concept, benefiting rural communities, enhancing the capacities of local institutions and creating an avenue for wider impact.

**Keywords:** Cooperation, Ethiopia, fodder production, spate irrigation

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# Central Asia II

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## Oral Presentations

- MAKSUD BEKCHANOV:  
**Cost-Effective Options of Climate Change Adaptation for Sustainable Agro-Ecosystem Enhancement in the Aral Sea Basin** 562
- YULDUZOY DJUMANIYAZOVA, MUROD SULTANOV, VINAY NANGIA, JOHN LAMERS:  
**Evapotranspiration-Based Irrigation Scheduling for Cotton in the Aral Sea Basin, Central Asia** 563
- MOHAMMADJAVAD SEGHATOLESLAMI, HASSAN FEIZI:  
**Studying the Possibility of Replacing Common Crop Plants with Medicinal Plants in Arid and Semi-Arid Areas: A Case Study in South Khorasan Province, Iran** 564
- FREDERIK VAN OUDENHOVEN:  
**Wisdom of the Mountains (film)** 565
-

## **Cost-Effective Options of Climate Change Adaptation for Sustainable Agro-Ecosystem Enhancement in the Aral Sea Basin**

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Growing water scarcity driven by climate change and consequent ecological degradation problems challenges researchers and policy makers for finding more effective yet affordable ways of water management. Especially in arid regions with heavy reliance on irrigated agriculture, such as the Aral Sea basin of Central Asia, water scarcity is an enormous threat for income and environmental security. Despite availability of a wide arsenal of tools to combat water scarcity their investment costs often prevent their wider implementation by water users and managers. This study assessed the water conservation potential and implementation costs of various water augmentation options in the Aral Sea Basin where unaccountable use of scarce water resources led to gradual depletion of one of the largest lakes in the world. For economic appraisal of potential technological improvements in irrigation sector, this research used a basinwide hydro-economic model that comprises a detailed water balance accounts across the sub-regions within the basin and relationships between water use and crop production. Modelling outcomes underlined the economic relevance of improving water distribution (conveyance) efficiency through canal lining and effective operational management in the lower reaches of the Amu Darya basin. Improved efficiency of water application in rice production was found out essential under growing water scarcity conditions, especially in the lower reaches of both Amu and Syr Darya basins. Meantime improved water application efficiency of gardens and orchards became recommendable in the upstream mountainous zones in Fergana Valley of the Syr Darya. The study argues that cooperation among state agencies (water management and coordination institutes, Finance Ministry, banks) and agricultural producers (private and cooperative farms) could be essential for the success of these economically relevant technological transformations.

**Keywords:** Amu and Syr Darya, environmental degradation, Fergana Valley, water application efficiency, water conservation

## Evapotranspiration-Based Irrigation Scheduling for Cotton in the Aral Sea Basin, Central Asia

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The Aral Sea Basin (ASB) in Central Asia is particularly known for its present and predicted deficiencies in available water which may even lead to increased conflicts. This necessitates a re-thinking of the irrigated production practices that consume virtually 90% of all water resources and in turn on the social and ecological consequences of such changes. The development of sustainable intensified production practices in ASB should focus with priority on the crop water demand for winter wheat and cotton since these predominate by far the cropping portfolios. Yet, the general lack of research resources limits the necessary field experiments, which can be compensated in part by modelling. Therefore, the DSSAT cotton-module was successfully calibrated and evaluated and next used for scenario assessments considering different levels of water availability. The developed key crop coefficient of 1.16 (Kc mid) matched extremely well with the previously, empirically measured 1.2 (Kc mid). When scheduling irrigation based on evapotranspiration (ET), results of scenario analyses indicated that up to 34% of water could be saved in the ASB without any changes in yields. The assessment of an ET-based irrigation scheduling according to existing soil types showed that up to 54,000 ha (ca 20% of the total irrigated area) could benefit from such water savings on loamy soils. When taking into account the temporal dynamics of ground water during the growing period water savings can be expected on ca. 63,000 ha (ca. 24% of the total irrigated area). Against the background of predicted demand under business-as-usual it is argued that the potential for water saving is huge, but this necessitates in-depth change in cultivating practices, which in turn needs a highly needed institutional and legal backing.

**Keywords:** Cotton, crop coefficient, DSSAT modelling, water saving

## Studying the Possibility of Replacing Common Crop Plants with Medicinal Plants in Arid and Semi-Arid Areas: A Case Study in South Khorasan Province, Iran

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Arid and semi-arid regions of the world are generally noted for their low primary productivity due to low and unpredictable water supply as well as soil infertility. Problems caused by weather conditions in arid and semi-arid regions have reduced yield of most crop plant in these areas. The climate change, on the other hand, has exacerbated environmental conditions in these areas. Thus, any changes in cropping systems leading to higher farm revenues could be useful in terms of income and job creation, and thus improve rural development. The cultivation of medicinal and aromatic plants is gaining interest because of increasing demand for these products. A high number of medicinal plants are adapted to arid and semi-arid regions. South Khorasan province in eastern Iran has been affected by climate change and drought for more than 15 years. This province is habitat of many important medicinal plants. Some of these, due to their adaptability to drought, have been considered as suitable replacement for common crops. In order to find appropriate replacement for common crops in this region, several experiments were conducted over the last decade, to test water stress effect on different medicinal plants. Based on these experiments, cumin (*Cuminum cyminum*), ajowan (*Carum copticum*), chicory (*Cichorium intybus*), roselle (*Hibiscus sabdariffa*), marigold (*Calendula officinalis*) and purslane (*Portulaca oleracea*) have been selected. Taking into account the production costs, marketable product, as well as market revenues, chicory showed the best economic result. The highest water productivity was found for chicory, cumin and roselle, respectively. The results also showed that, sugar beet and cotton cultivation in South Khorasan is unjustified.

**Keywords:** Job creation, net profit, production costs, water productivity

## Wisdom of the Mountains

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The Pamiri people in Tajikistan and Afghanistan have long been among the most isolated communities in the world. They live according to centuries old traditions, yet increasingly must deal with Western influences entering their lives. One of the areas in which these changes are most visible is on the dinner table, where foreign foods are replacing traditional ones. The consequences for local crop diversity (the Pamirs are considered a globally important centre of diversity for important fruit and grain crops) are profound.

Together with local agricultural scientists and fellow researcher Jamila Haider, I documented Pamiri crop varieties and their numerous uses for food and medicine. It resulted in the publication of *With our own hands*, a 688 page book highlighting the critical role of the people of the Pamirs as custodians of their food, seeds and traditions. It is also the first document to chronicle this hitherto orally transmitted (food) culture in printed form, in a manner accessible to the Pamiri people themselves. Every community, school and community centre in the region received a copy.

In the film *Wisdom of the Mountains* we travel to the Pamirs with the first copies of our book, bringing it back to the farmers, scientists, cooks and teachers who helped make it. Through their stories we explore the tremendous contrasts between the Afghan and Tajik Pamirs, between visions of progress and development. And we learn how osh is made, one of the most iconic dishes of the Pamirs.

**Keywords:** Afghanistan, food culture, Pamir, Tajikistan



# Index of Authors

## A

- Abdul Rahman, Nurudeen ..... 128
- Abdullaeva, Yulduzkhon ..... 164
- Abdurasulova, Gulbahar ..... 329
- Abebie, Techane Gonfa ..... 423, 510
- Abekoe, Mark .. 109, 122
- Abel, Benard Otieno 445, 455
- Abenney-Mickson, Stephen ..... 109, 384
- Abera, Bayuh Belay . 208, 210
- Abolore, Bello, R. ... 426
- Achieng, John ..... 178
- Achigan-Dako, Enoch G. .... 192
- Adam, Anna ..... 134
- Adamseged, Muluken Elias ..... 480
- Adamtey, Noah . 129, 229
- Adarkwah, Charles .. 376
- Addo, Ahmad ..... 384
- Adebi, Yasmina ..... 58
- Adegbenro, Muiyiwa . 378
- Adeyosoye, O. I. .... 361
- Adgo, Enyew ..... 158
- Adhikari, Keshab .... 273
- Adi, Amien Fahrianto ..... 344
- Adler, Cornel .... 94, 385
- Admassie, Assefa ... 512
- Aenis, Thomas ..... 53
- Afifah Rahmi, Afifah 388
- Afolabi, K. D. .... 361
- Afriyie, Lydia ..... 481
- Agamy, Essam ..... 94
- Agarwal, Bina ..... 13
- Agbede, J. Oluwasola 378
- Agbona, Afolabi .... 426
- Agbossou, Euloge K. 169
- Aghamir, Fateme .... 196
- Ahmad Zahir, Zahir . 241
- Ahmad, Ashfaq .... 261
- Ahmad, Ijaz ..... 370
- Ahmad, Nasim ..... 370
- Ahmed, Fauziatu .... 109
- Ahmed, Mohamed ... 357
- Ahrenfeldt, Jesper .. 109, 384
- Aina, Femi ..... 426
- Ajwera, Flora ..... 178
- Akello, Juliet ..... 87
- Akhtar, Pervez ..... 244
- Akinlolu, Adekunle Oluyemi .. 354
- Akoto-Danso, Edmund Kyei .... 123
- Akponikpe, Pierre Bienvenu ..... 169
- Akter, Mst. Sharmin . 297
- Akuwa, Kingsley C. . 426
- Akçakara, Hazal .... 467
- Al Agbar, Majdee ... 342
- Al Qaiseh, Wael .... 342
- Al-Beitawi, Nafez A. 358
- Al-Riffai, Perrihan ... 251
- Alban Lopez, Noe .. 456, 461
- Alemeyehu, Getachew ..... 158
- Alemu, Bamlaku Alamirew ..... 104, 486
- Ali Ahmad Korori, Soudabeh ..... 541
- Ali, Asep Indra Munawar ..... 368, 369
- Ali, Mazen ..... 357
- Alibu, Simon ..... 194
- Aliev, Kumarbek 270, 277
- Almeida, Roberto G. 239, 242
- Almeida-Cortez, Jarcilene ..... 31
- Altmann, Monique .. 193
- Alvarado Capó, Yelenys ..... 154
- Alvarez, Miguel .. 22, 23, 35
- Amacker, Michèle .... 67
- Amede, Tilahun .... 560
- Amelung, Wulf ..... 124
- Amgai, Resham Babu 213
- Aminou, Ali Maman . 156
- Amjath Babu, T.S. ... 511
- Amoah, Kwadwo Kusi ..... 109
- Amoakwah, Emmanuel ..... 109, 131
- Amouzou, Kokou Adam-bounou ... 260
- Andika, Darius O. ... 134
- Andriamazaoro, Herimihamina ... 474
- Andrieu, Nadine .... 172



Angarawai, Ignatius Ijan- tiku . 205, 217	Bae, Sangeun . . . . . 327	Belayneh, Hailemariam Teklewold 483
dos Anjos, Filomena . 550	Baibagysov, Azim . . 270, 532	Bellingrath-Kimura, Sono- ko Dorothea . . . . . 259
Anyu, Magnus . . . . . 371	Baidoo, Isaac . . . . . 109	Bello, F.A. . . . . 361
Apdini, Titis . . . . . 373	Balkema-Buschmann, Anne . . . . . 42	Ben Mahmoud, Ziyad 358
Aragaw, Habtamu S. 182, 410	Balume, Isaac . . . . . 135	Ben Mimoun, Mehdi . 290
Arango, Jacobo 126, 137, 141	Bandyopadhyay, Ranajit . . . . . 86, 87, 89	Benbya, Abdellah . 27, 28
Arasio, Raphael . . . . . 335	Banout, Jan . . . . . 54, 396	Bender, Laura . . . . . 301
Arboleda, Victor . . . . 406	Baranowski, Elisabeth . . . . . 532	Benito, Marta . . . 126, 137
Arenas, Laura . . . . . 172	Barati, Ziba . . . . . 401	Benmoussa, Haifa . . . 290
Arevalo, Ashly . . . . . 126	von Bargen, Susanne . 77, 79	Bentson, Sam . . . . . 406
Arevalo-Peñaranda, Emilio . . . . . 77	Barron, Jennie . . 228, 235	Berger, Beatrice . . . . . 168
Arigbede, O. Moses . 354	Bartling, Mona . . . . . 55	Berger, Thomas . . . . . 265
Armengot, Laura . 80, 229	Bartolini, Pietro . . . . . 394	Bernard, Marc . . . 558, 559
Arthur, Emmanuel . . 109, 131	Basch, Gottlieb . 133, 294	Bert, Wim . . . . . 92
Asante, Felix A. . . . . 316	Bashir, Elfadil . . . . . 219	Bertelsen, Astrid . . . . 337
Asch, Folkard . . . 51, 158, 207–211, 215, 227, 239, 240, 242, 243, 252	Bassey, Nkoyo . . . . . 437	Bessler, Holger . . . . . 134
Aseta, Antony . . . . . 414	Bauer, Christian 530, 537	Betancourt Vaquez, Mónica . . . . . 77
Asiedu, Robert . . . . . 426	Baumann, Maximilian . . . . . 550	Betancur Corredor, Bibiana . . . . . 56
Atehnkeng, Joseph 87, 89	Baumgartner, Sabine . . 51	Betemariam Aynekulu, Er- mias . . . . . 274
Augusto, Joao . . . . . 87	Bautze, Lin . . . . . 180	Bett, Eric . . . . . 444
Aung, Pyi Soe . . . . . 49	Baylis, Katherine . . . . 272	Beuchelt, Tina . . . 111, 467
Aung, Yee Mon . 463, 465	Bebe, Bockline . 336, 374, 460	Bharati, Luna . . . . . 236
Awiszus, Sebastian . . 107	Beber, Caetano Luiz . 393	Bhat, Shripad . . . . . 445
Ayaga, George . . . . . 178	Becker, Mathias 139, 168, 181, 184, 185, 194, 260, 485	Biahimo, Sri Dewi . . . 284
Ayana, Alemgena . . . 416	Beckmann, Volker . . . 532	Biber-Freudenberger, Lisa . . . . . 99, 113, 179
Ayieko, David Michael . . . . . 444	Beckschäfer, Philip 30, 62	Bielders, Charles 169, 487
Ayisi, Kingsley K. . . . 116	Beed, Fenton Douglas . 75	Biesalski, Hans Konrad . . . . . 419, 420, 422, 425
Ayuk, Ausaji . . . . . 371	Behn, Kai . . . . . 22, 35	Bigler, Christine . . . . . 67
Azhdari, Ghanimat . . . 40	Beitzen-Heineke, Elisa . . . . . 84, 85	Birachi, Eliud . . . . . 67
<b>B</b>	Beitzen-Heineke, Wilhelm . . . . . 84, 85	Birke, Fanos Mekonnen . . . . . 298
Babu, Suresh . . . . . 90	Bekchanov, Maksud . 531, 562	Birkenberg, Athena . . 140
Bach, Carine Inês Schröter . . . . . 366	Belachew, Tefera . . . . 416	Birner, Regina . . . . . 102, 140, 326, 389, 507, 520
Backhaus, Kristina . . 550		

- Bisseleua, Herve ..... 81  
 Blaettler, Dominic .... 63  
 Blagodatskiy, Sergey 125,  
 255  
 Blaser, Sebastian R.G.A.  
 ..... 152  
 Boedecker, Julia 301, 413,  
 415  
 Boehlke, Nikolas .... 105  
 Böhme, Michael .... 159  
 Börner, Jan . 99, 113, 266  
 Böttger, Christian ... 363  
 Bokelmann, Wolfgang  
 438, 445, 462,  
 473, 509  
 Boktiar, S.M. .... 273  
 Bolaji, Thanni ..... 186  
 Boller, Thomas ..... 153  
 Bolliger, Adrian 345, 346  
 Bolwig, Simon ..... 109  
 Bonaiuti, Enrico ..... 394  
 Bonatti, Michelle ... 338,  
 405  
 Bonierbale, Merideth 215  
 Bonneau, Xavier .... 170  
 Borchard, Nils ..... 174  
 Borgemeister, Christian  
 .. 56, 179, 304,  
 308, 429  
 Borko, Tafese Boshu . 419  
 Bortl, Ludvík ..... 430  
 Botero, César ..... 137  
 Boureima, Amadou .. 331  
 Bozorgparvar, Elham 542  
 Braun, Boris ..... 332  
 Bravo, Aura ..... 464  
 Breisinger, Clemens . 251  
 Breuer, Lutz ..... 53  
 Breuning-Madsen, Henrik  
 ..... 109, 122  
 Brunori, Gianluca ... 296  
 Bryan, Elizabeth .... 231  
 Buerkert, Andreas .. 123,  
 142, 143, 244  
 Büttner, Carmen .. 77, 79  
 Bundala, Nyamizi ... 338,  
 425  
 Bunn, Christian . 55, 191,  
 497  
 Burghof, Sonja ..... 35  
 Burkart, Stefan . 364, 456,  
 461, 464, 471,  
 472  
 Butterbach-Bahl, Klaus  
 173, 183, 351,  
 368, 369, 374,  
 375  
 Byarugaba, Audery .. 372
- C**
- Cadisch, Georg ... 51, 80,  
 125, 132, 138,  
 141, 241, 249,  
 254, 255, 258,  
 412  
 Caguiat, Joanne . 216, 221  
 Callo-Concha, Daniel  
 ..... 182, 410  
 Camara, Alimou ..... 42  
 Carampatana, Jake .. 216,  
 221  
 Casas Reategui, Ruben  
 ..... 430  
 Casierra Posada, Fánor 77  
 Caspersen, Lars .... 533  
 Castañeda Cárdenas, Adri-  
 ana ..... 77  
 Castillejos Cruz, Carlos  
 ..... 91  
 Castro, Fabio .... 55, 191  
 Castro-Montoya, Joaquín  
 ..... 362  
 Cattan, Philippe ..... 198  
 Chagüezá, Yamileth . 126,  
 137  
 Charry, Andrés . 456, 461,  
 464, 466  
 Chatterton, Paul ..... 263  
 Chavarria, Elbis ..... 24  
 Chekanai, Vongai .... 155  
 Chemining'wa, George 73  
 Chepkoech, Caroline 145  
 Chepngeno, Joyce ... 469  
 Chicamisse, Luisa Mutisse  
 ..... 550  
 Chigemezu, Charles . 186  
 Chikowo, Regis ..... 155  
 Chilombo, Andrew ... 60  
 Chimuleke, Munthali 446,  
 469  
 Chinkhata, Dennis ... 553  
 Chirinda, Ngonidzashe  
 ..... 172  
 Chitambo, Oliver ..... 76  
 Chiveu, Josiah ..... 418  
 Christian Landry, Djuideu  
 Tchouamou 81  
 Christmann, Stefanie . 27,  
 28  
 Chuma, Boshuwenda An-  
 dre .. 208, 211  
 Ciannella, Rodrigo .. 278  
 Cierjacks, Arne ..... 31  
 Conrad, Christopher .. 48,  
 530  
 Cordoba, Diana Marcela  
 ..... 439  
 Cotter, Marc 51, 208–211  
 Cotty, Peter ..... 87  
 Coulibaly, Drissa ..... 21  
 Coulibaly, Kalifa .... 294  
 Crewett, Wibke ..... 438  
 Cruz Rivera, Yaremi Karina  
 ..... 479  
 Csaplovics, Elmar ... 494  
 Cuellar, Wilmer ..... 77  
 Cumbana, Ivo ..... 550  
 Cunha, Marcelo ..... 458  
 Cutler, Joseph .... 77, 79  
 Câmara, Gilberto .... 263

- D**
- D’Aiuto, Chris ..... 550  
D’Haese, Marijke ... 317  
Dabasso, Buke ..... 377  
Dabasso, Bulle Hallo 325  
Dalaa, Mustapha .... 497  
Dalemans, Floris .... 101  
Damnyag, Lawrence . 481  
Danso, Isaac ..... 256  
Dao, Juliane ..... 143  
Darr, Dietrich ... 61, 313,  
446, 469, 533  
Dassou, Olivier ..... 170  
Daum, Thomas ..... 389  
De Sousa, Gleice Alves  
..... 100  
Debarry, Annapia .... 508  
Dede, Christian ..... 400  
Degrande, Ann ..... 447  
Deihimfard, Reza .... 196  
Del Rio, Martha ..... 439  
Dela Cruz, Quirino .. 216  
Delgadillo Jaime, Estepha-  
nia E. .... 507  
Della Rossa, Pauline . 198  
Deller, Markus ..... 533  
Demmler, Kathrin Maria  
..... 428  
Denich, Manfred . 56, 105  
Dewi, Sonya ... 263, 284  
Diallo, Abdoulaye ... 217  
Diallo, Bocar ..... 217  
Díaz, Enna ..... 126  
Diaz, Manuel ... 456, 461  
Diaz-Pines, Eugenio . 173  
Dickhoefer, Uta 345, 346,  
362, 368, 369  
Diederich, Sandra .... 42  
Dieckrüger, Bernd .. 139,  
234  
Dietel, Kristin ..... 168  
Dietz, Silvia ..... 548  
Dijkstra, Jan ..... 373  
Dipierri, Ana Alicia . 237
- Dippel, Cornelia ..... 85  
Dixon, Alfred Gilbert 426  
Djumanizayova, Yulduzoy  
..... 563  
Djurupova, Bermet .. 533  
Dolch, Erik ..... 550  
Dombinov, Vitalij ... 171  
Domke, Maxi ..... 305  
Domptail, Stephanie . 489  
Dorvlo, Selorm Y. .. 109,  
384  
Du Preez, Christiaan C.  
..... 144  
Dubovyk, Olena ..... 64  
Dürr, Jochen ... 459, 549  
Duncan, Alan ..... 254  
Dupré, Marie ..... 197  
Dwiyanti, Elissa ..... 284  
Dzhakypbekova, Klara  
..... 533  
Dzudzor, Makafui ... 316
- E**
- Ecker, Olivier ..... 428  
Eduah, Joseph Osafo 109,  
122  
Egenolf, Konrad ..... 141  
Eichler-Loebermann, Bet-  
tina ..... 154  
Eiden, Hanns-Christoph  
..... 548  
Ekeocha, A.H. .... 361  
Ekesi, Sunday ..... 95  
El Bilali, Hamid ..... 443  
El Didi, Hagar ..... 231  
El Rhaffari, Lhoussaine  
..... 394  
El Salamouny, Said ... 93  
Elhadi, Yazan ..... 333  
Elias, Marlene ..... 504  
Elias, Michael ..... 59  
Ellssel, Pierre ..... 190  
Elnasikh, Sara ..... 231  
Elwers, Silke ..... 187
- Enciso, Karen .. 456, 461,  
464  
Enesi, Rebecca ..... 186  
Engel, Erik ..... 550  
Engels, Christof ..... 134  
Engler Palma, Alejandra  
..... 448  
Eraaliev, Maksat .... 270  
Ergezinger, Lara ..... 204  
Ershaid, Rawda ..... 342  
Escobar, Neus .. 112, 113  
Espinell, Maria Luisa . 343  
Estrada-Carmona, Natalia  
..... 40  
Estrella, Andrea ..... 435  
Esyrev, Oleg ..... 545  
Evang, Esther ..... 469  
Ewert, Frank ..... 161
- F**
- Fahim, Soumia ..... 394  
Falk, Thomas ..... 233  
Farafan, Evelyn ..... 215  
Fatokun, Christian ... 163  
Faust, Heiko ..... 495  
Faye, Babacar ..... 257  
Faße, Anja ..... 519  
Fehle, Pia ..... 63  
Feizi, Hassan ..... 564  
Felicitas, Ambele Chaba  
..... 81  
Ferenczi, Zoltán M. . 462,  
509  
Fernandes, Sergio Rodrigo  
..... 366  
Fernandez, Raúl ..... 295  
Fernández Cusimamani,  
Eloy ..... 32  
Ferrari, Leone ..... 436  
Ferreira, Enderson ... 160  
Feye, Getachew Legese  
..... 483  
Fiaboe, Komi ..... 76, 95  
Fiege, Karin ..... 550

- Fischer, Gundula 402, 513  
 Fischer, Kerstin ..... 42  
 Fischer, Sahrah . 138, 412  
 Flekac, Stanislav .... 396  
 Fliessbach, Andreas . 129  
 Förster, Jan Janosch . 112,  
 113  
 Fogliano, Vincenzo .. 411  
 Fongar, Andrea . 414, 555  
 Fonseca-Zang, Warde An-  
 tonieta da . 100  
 Fonte, Steven ..... 130  
 Foord, Stefan ..... 116  
 Forkour, Gerald ..... 48  
 Forsido, Sirawdink  
 Fikreyesus 416  
 Forster, Lea ..... 91  
 Foundjem-Tita, Divine  
 ..... 447  
 Frank, Anke S.K. .... 116  
 Freyer, Bernhard .... 145,  
 158, 190  
 Fredy Mauricio, Cruz Bar-  
 rera ..... 168  
 Frei, Michael ..... 204  
 Frija, Aymen ..... 480  
 Frimpong, Kwame Agyei  
 ..... 109, 131  
 Fromm, Ingrid ..... 436  
 Fürst, Christine ..... 65  
 Funk, Christoph ..... 53  
 Fuss, Sabine ..... 263
- G**
- Gabiri, Geoffrey ..... 35  
 Gachagua, Marygoretti 88  
 Gachuiiri, Agnes ..... 286  
 Gachuiiri, Charles ... 351,  
 375  
 Gaesing, Karin . 300, 303  
 Gaiser, Thomas 161, 256,  
 257  
 Gakige, Jesse ..... 351  
 Gamar, Yasir ..... 219  
 Garbati Pegna, Francesco  
 ..... 394  
 Garcez Neto, Américo  
 Frões 366, 373  
 Garcia Guarin, Pedro Julian  
 ..... 390  
 Garcia, Edwin ..... 24  
 Garcillano, Marlon .. 221  
 Garcês, Leila ..... 74  
 Garibay, Salvador .... 91  
 Garschagen, Matthias 482  
 Gasore, Elie-Rene ... 211  
 Gaspard, Frédéric .... 57  
 Gattinger, Andreas .. 180  
 Gaudin, Amélie ..... 130  
 Gebauer, Jens .. 115, 469,  
 533  
 Gebert, Marina ..... 553  
 Gebeyehu, Kelemework  
 Geleta .... 515  
 Gebrehaweria, Gebreg-  
 ziabher ... 235  
 Gebrekidan, Bisrat Haile  
 ..... 484  
 Gebreyohanes, Getaw  
 Tadesse .. 442  
 Geisen, Rolf ..... 88  
 Gendall, Harriet ..... 39  
 Germer, Jörn ... 158, 240  
 Gerold, Gerhard ..... 229  
 Gerster-Bentaya, Maria  
 ..... 301  
 Gevorgyan, Emil 296, 317  
 Ghanney, Philip ..... 165  
 Ghazaryan, Gohar .... 64  
 Ghrab, Mohamed .... 290  
 Giese, Marcus . 239, 242,  
 255  
 Giller, Ken ..... 155  
 Giri, Bhoopander .... 157  
 Gitonga, M Zachary . 151  
 Glas, M. Gracia ..... 424  
 Glasner, Björn ..... 184  
 Glatzle, Sarah .. 239, 242  
 Glowacki, Sebastian . 362  
 Gödecke, Theda 309, 414,  
 555  
 Görg, Louisa ..... 85  
 Goetze, Dethardt . 21, 193  
 Gogo, Elisha O. .... 392  
 Goldberg, Stefanie ... 125  
 Gombert, Alina Joana 533  
 Gomez, Carlos A. ... 365  
 Gondah, Jada ..... 205  
 Gonella Jimenez, Andrea  
 ..... 266  
 Gonzalez, Carolina .. 439  
 González Álvarez, Alejan-  
 dro ..... 40  
 Goopy, John ... 351, 368,  
 369, 374, 375  
 Goudiaby, Mame Fa-  
 toutmata ... 83  
 Gowele, Victoria 338, 425  
 Gownipuram, Ravindra-  
 varma .... 362  
 Graef, Frieder .. 259, 285,  
 306, 398, 405,  
 507  
 Gramaje, Leonilo ... 216,  
 221  
 Gramzow, Andreas .. 513  
 Granda Mora, Klever Ivan  
 ..... 154  
 Grau, Felix ..... 167, 174  
 de Groote, Hugo .... 151  
 Groschup, Martin H. .. 42  
 Gross, Jürgen ..... 85  
 Grote, Ulrike ..... 519  
 Grotelüschen, Kristina  
 ..... 184  
 Groth, Juliane ..... 506  
 Gruberg Cazón, Helga 40  
 Grundler, Florian M. W.  
 ..... 76  
 Grundmann, Philipp . 103  
 Grundmann, Tim Julian  
 ..... 167

- Guamán Díaz, José Francisco ..... 154  
 Guarino, Luigi ..... 20  
 Gubelt, Angela ..... 113  
 Gumisiriza, Robert .. 108  
 Gupta, Saurabh ..... 102  
 Gurung, Tayan ..... 273  
 Gusvita Widia, Gusvita  
 ..... 388  
 Guta, Dawit ..... 238  
 Gutierrez Solis, Jhon  
 Freddy ... 137,  
 364, 461  
 Gweyi-Onyango, Joseph  
 Patrick ... 134
- H**
- H. H. Deafalla, Taisser  
 ..... 494  
 Habte, Tsigie-Yohannes  
 ..... 469  
 Hadersdorfer, Johannes  
 ..... 552  
 Häring, Volker . 123, 142,  
 143  
 Hafner, Johannes 285, 405  
 Hagar, El Didi ..... 251  
 Haidery, Aqila ..... 63  
 Hailemichael, Selam . 517  
 Halaweh, Wael ..... 342  
 Halle, Ernestine Mefor  
 ..... 507  
 Hammond, Stacy ..... 34  
 Handa, Collins ..... 23  
 Hanna, Rachid ..... 90  
 Harry, Bassey ..... 371  
 Hartman, Glen L. .... 75  
 Harun, Murithi ..... 75  
 Hasanah, Yaya ..... 214  
 Hash, Charles Tom .. 205,  
 220  
 Haudenschild, James .. 75  
 Haukeland, Solveig 76, 92  
 Hauser, Michael ..... 443  
 Hauser, Stefan ..... 186  
 Haussmann, Bettina I.G.  
 . 205, 217, 220  
 Hawumba, Joseph ... 108  
 Heckelei, Thomas ... 484  
 Hegazi, Esmat ..... 94  
 Hehl, Ann-Kathrin .. 138  
 Heim, Anita ..... 52  
 Heinke, Jens ..... 228  
 Heinrich, Jürgen ..... 66  
 Heni, Jakob ..... 138  
 Henriksen, Ulrik 109, 384  
 Hensel, Oliver .. 38, 108,  
 386, 400, 403,  
 416  
 Heri-Kazi Bisimwa, Aimé  
 ..... 487  
 Herm-Stapelberg, Antonia  
 ..... 337  
 Hermann, Katharina .. 84  
 Hermans, Kathleen .. 506,  
 524  
 Herrmann, Ludger .. 152,  
 156  
 Herrmann, Roland ... 514  
 Hilali, Muhi El-Dine . 341  
 Hilderink, Henk ..... 50  
 Hilger, Thomas . 80, 138,  
 140, 241, 261,  
 412  
 Hilgers, Linda ..... 30  
 Hincapie, Belisario .. 364  
 Hodgkin, Toby ..... 40  
 Hoelle, Julia ..... 215  
 Hoenen, Thomas ..... 42  
 Hoeschle-Zeledon, Irmgard  
 ..... 128  
 Hoffmann, Heide .... 550  
 Hollaus, Alexander .. 136  
 Hommels, Martin ... 469,  
 533  
 Hornidge, Anna-Katharina  
 ..... 299, 308  
 Hossain, Md Kamal ... 38
- Hosseini, Mohammad 543  
 Houška, Jakub ..... 417  
 Houdegbe, Carlos A. 192  
 Houessou, Laurent G. . 58  
 Huber-Sannwald, Elisabeth  
 ..... 36  
 Hübner, Severin 239, 242  
 Hülsebusch, Christian 59,  
 330, 336, 352  
 Hughes, Karl ..... 272  
 Huluka, Admassu Tesso  
 ..... 423  
 Humbert, Pascal .. 84, 85  
 Hurtado, Jhon Jairo . 464,  
 466  
 Hussain, Khalid ..... 261  
 Hutchinson, Margaret . 73  
 Huyskens-Keil, Susanne  
 ..... 392
- I**
- Ibragim, Adiya ..... 545  
 Ibragimova, Nailya .. 545  
 Idel, Anita ..... 330  
 Iklasov, Margulan ... 532  
 Ilona, Paul ..... 426  
 Ilyas, Ayesha ..... 261  
 Impens, Reinout ..... 170  
 Ingabire, Chantal ..... 67  
 Irmansyah, Teuku ... 214  
 Irungu, Patrick ..... 325  
 Isaaka, Ahmad ..... 220  
 Isele, Judith ..... 330  
 Islam, Md. Rafiqul .. 127  
 Islam, Rafiq Khandakar  
 ..... 131  
 Islam, Tahmina ..... 212
- J**
- Jabaty, Juliet ..... 42  
 Jablonowski, Nicolai David  
 ..... 162, 171  
 Jackson, Robert ..... 73  
 Jäckering, Lisa . 309, 555

- Jäger, Matthias . 464, 466  
Jaime Acevedo, Diana  
    Ximena . . 265  
Jakobs-Schoenwandt, Desirée . . 82, 168  
Jalloh, Abdulai . . . . . 186  
Jannoyer, Magalie . . . 198  
Janssen, Peter . . . . . 50  
Janudianto . . . . . 281  
Janz, Baldur . . . . . 183  
Jassogne, Laurence . . 497  
Jatta, Raymond . . . . . 105  
Jaza Folefack, Achille Jean  
    . . . . . 61  
Jemal, Omarsherif Mohammed . 182,  
    410  
Jenny, Katharina . . . . 436  
Jensen, Henning Høgh  
    . . . . . 145  
Jiménez-Martínez, Marcos  
    . . . . . 65  
Jonsyn-Ellis, Felixtina 42  
Joosten, Matthieu . . . . 75  
Jordan, Irmgard 412, 424,  
    427  
Joseph, Philipo . . . . . 513  
Junge, Helmut . . . . . 168
- K**
- Kabi, Fred . . . . . 372  
Kahimba, Frederick C.  
    . . . . . 259  
Kahmen, Ansgar . . . . 153  
Kahneh, Ehsan . . . . . 166  
Kaimba, George Kinyua  
    . . . . . 469  
Kalousová, Marie 33, 188  
Kalumikiza, Zione . . . 553  
Kamau, Elizabeth . . . 427  
Kamau, Juliet Wanjiku  
    . . . . . 179  
Kamiri, Hellen . . . . . 23  
Kampermann, Ivonne 132  
Kamrad, Marie . . . . . 424  
Kan, Elena . . . . . 538  
Kandeler, Ellen . . . . 164  
Kangalawe, Richard Y. M.  
    . . . . . 59  
Kanju, Edward . . . . . 426  
Kante, Moctar . . . . . 217  
Kapgen, Diane . . . . . 505  
Karriem, Abdulrazak 550  
Karunaratne, K.H.M.I.  
    . . . . . 174  
Karwat, Hannes . . . . . 141  
Kaseeva, Gulnaz . . . . 533  
Kashongwe, Basole Olivier  
    . . . . . 336  
Kasili, Remmy . . . . . 399  
Kassam, Daud . . . . . 553  
Katanha, Anyway . . . 195,  
    496  
Kaufmann, Brigitte . 295,  
    315, 325, 335,  
    468  
Kaweesa, Sara . . . . . 133  
Kayitakire, Francois . 331  
Keding, Gudrun B. . . 415,  
    423  
Kefelegn, Kebede Kefenie  
    . . . . . 327  
Keffie, Tibebelessie 420  
Kegode, Hilda . . . . . 272  
Kehlenbeck, Katja . . 114,  
    115, 418  
Kelboro, Girma 299, 308,  
    483  
Kemausor, Francis . 384  
Kengwa, Venance . . . 353  
Kenjabaev, Shavkat . . 537  
Kennedy, Gina . . . . . 413  
Kerre, Francis . . . . . 249  
Ketter, Christina . . . . 560  
Khadka, Ambika . . . . 236  
Khafagi, Wedad E. . . . 94  
Khalil, Altyn . . . . . 532  
Khamzina, Asia 234, 262  
Khasanah, Ni'matul . 262,  
    284  
Khatiwada, Shambhu  
    Prasad . . . 213  
Kiarri, Eustace . . . . . 444  
Kiboi, Milka . . . . . 129  
Kiese, Ralf . . . . . 183  
Kihara, Job . . . . . 178  
Kimani, Wilson . . . . . 219  
Kimaro, Anthony . . . 285,  
    405  
Kimiti, Jacinta . . . . . 286  
Kinabo, Joyce . . 338, 422,  
    425  
Kindermann, Liana . . 116  
Kinsel, Emily . . . . . 337  
Kiplagat, Andrew . . . 300,  
    303  
Kirigia, Dinah . . . . . 399  
Kirscht, Holger . . . . . 90  
Klein, Doris . . . . . 530  
Kleinn, Christoph . 30, 62  
Kluger, Lotta Clara . . 253  
Knierim, Andrea 298, 301  
Koech, Oscar . . . . . 333  
König, Bettina . . . . . 312  
Köpke, Ulrich . . 181, 184,  
    194  
Kohlmann, Bert . . . . . 406  
Kok, Marcel . . . . . 50  
Koller, Robert . . . . . 162  
Konaté, Souleymane . . 21  
Koomson, Eric . 249, 254  
Korir, Daniel . . . 368, 369,  
    375  
Koroma, Bashiru . . . . 42  
Kottusch, Charlotte . . 263  
Kotu, Bekele Hundie 128  
Kousar, Rehana . . . . . 370  
Kraus, David . . . . . 183  
Krause, Henning . . . . 519  
Krauss, Gunther . . . . 257  
Krawinkel, Michael . 427,  
    469

Kraxner, Florian . . . . .	263	Lang, Rong . . . . .	125	Lippe, Melvin . . . . .	258
Kreipe, Leonie . . . . .	493	Langer, Juliane . . . . .	77, 79	Liu, Fulai . . . . .	109
Krell, Vivien . . . . .	82	Lannerstad, Mats . . . . .	228	Liu, Hongxi . . . . .	255
Kreye, Christine . . . . .	186	Lanzanova, Denis . . . . .	275	Lloyd, Jessica . . . . .	243
Kropff, Martin . . . . .	14	Lara Reimers, Eduardo		Loaiza Usuga, Juan Carlos	
Kuchenbuch, Ralf . . . . .	533	Alberto . . . . .	32	. . . . .	56
Kugbe, Joseph . . . . .	165	Lara Rodriguez, Eduardo		Loaiza, Sandra . . . . .	172
Kugler, Florian . . . . .	469, 533	Antonio . . . . .	32	Loboguerrero, Ana Maria	
Kugonza, Jane . . . . .	372	Larbi, Asamoah . . . . .	128	. . . . .	172
Kuhn, Armin . . . . .	232, 437	Larsen, Daniel Ellehammer		Löffler, Jörg . . . . .	144
Kulakow, Peter . . . . .	426	. . . . .	337	Löw, Fabian . . . . .	64, 530
Kulmyrzaev, Asylbek	533	Latif, Sajid . . . . .	107, 401	Loina, Rose . . . . .	353
Kumar, Lava . . . . .	90	Le Bail, Marianne . . . . .	198	Lojka, Bohdan . . . . .	33, 417
Kumar, Shalander . . . . .	233	Le Gal, Pierre-Yves . . . . .	197	Lokoyel, Rose . . . . .	303
Kumar, Sudhir . . . . .	236	Le, Anh Hung . . . . .	159	Lompo, Désiré Jean-Pascal	
Kungu, James . . . . .	289	Le, Quang Bao . . . . .	394	. . . . .	143
Kuntosch, Anett . . . . .	312	Leandro, Wilson Mozena		Londhe, Sunil . . . . .	273
Kunyanga, Catherine	391	. . . . .	100	Loos, Tim K. . . . .	104, 486,
Kuria, Peter . . . . .	133	Lebailly, Philippe . . . . .	340	502	
Kusia, Elizabeth . . . . .	429	Leder, Stephanie . . . . .	523	Lord, Emma Jane . . . . .	311
Kussul, Nataliia . . . . .	64	van der Lee, Jan . . . . .	460	Losada Acosta, Orlando	
Kusumawicitra, Eshan		Leemhuis, Constanze . . . . .	35,	. . . . .	77
. . . . .	344	139		Losilla, Luis . . . . .	448
Kwesiga, Julius . . . . .	181	Leeuwis, Cees . . . . .	297	Lozano Osorno, Fernando	
Kyomugisha, Harriet . . . . .	440	Lefore, Nicole . . . . .	235	. . . . .	395
<b>L</b>		Lehndorff, Eva . . . . .	124	Lubungu, Mary . . . . .	326
La, Nguyen . . . . .	280	Leiser, Willmar L. . . . .	217	Ludwig, Lea Luise . . . . .	330
Läderach, Peter . . . . .	140	Leite, Athaydes F. . . . .	100	Ludwig, Till . . . . .	488
Lagat, Job . . . . .	438	Lelarge, Manon . . . . .	296	Lüchau, Christian . . . . .	77, 79
Lakemond, Catriona M.M.		Lelea, Margareta . . . . .	468	Lückstädt, Christian . . . . .	359
. . . . .	411	Leta, Gerba . . . . .	299	Luedeling, Eike . . . . .	248, 275,
Lakner, Sebastian . . . . .	393	Leuner, Olga . . . . .	417	288–290	
Lambert, Christine . . . . .	419,	Leuzinger, Tiphaine . . . . .	63	Lukuyu, Ben . . . . .	372, 402
420		León-Sicard, Tomás E.		Lundy, Mark . . . . .	497
Lamers, John . . . . .	260, 262,	. . . . .	490	Luning, Pieternel A. . . . .	411
531, 563		Liaghati, Houman . . . . .	196,	Lusambo, Leopold . . . . .	285
Lana, Marcos Alberto	259	441		Lutz, Clemens . . . . .	442
Landaverde Gonzalez,		Lichtenberg, Silke . . . . .	36	Lyimo-Macha, Joyce	457
Patricia . . . . .	26	Liese, Bernhard . . . . .	185	<b>M</b>	
Landers, Ivan . . . . .	243	Liman, Issoufou . . . . .	289	Maat, Harro . . . . .	297
Landmann, Dirk . . . . .	521	Link, Dorothea . . . . .	88	Madaleno, Isabel . . . . .	29
Lang, Kathinka . . . . .	138	Linsenmair, Karl-Eduard		Madani Mashaei, Elaheh	
Lang, Petra . . . . .	270	. . . . .	21	. . . . .	541
		Linstädter, Anja . . . . .	116, 324		

- Mader, Lisa ..... 80  
Maertens, Miet ..... 101  
Maftei, Marius ..... 356  
Maggioni, Heloise ... 366  
Mahajan, Pramod ... 404  
Mahdavi Damghani,  
Abdolmajid  
..... 196  
Mahla, Anika ... 300, 303  
Mahlouji, Mansoure . 441  
Mahmoud El Abbas,  
Mustafa .. 494  
Mahmoud, Tarig Elsheikh  
..... 469  
Mahuku, George ..... 75  
Mahungu, Nzola-Meso  
..... 426  
Maina, Anthony ..... 313  
Maina, Erick ..... 427  
Makokha, Anselimo . 377  
Malhis, Ihab ..... 342  
Malima, Gabriel ..... 402  
Mamadjanov, Davlet . 533  
Manditsera, Faith Angeline  
..... 411  
Mandák, Bohumil .... 33  
Maneerattanachaiyong,  
Sonthana .. 40  
Mangesho, Walter E. . 353  
Maniania, Nguya Kalemba  
..... 95  
Manka'abusi, Delphine  
..... 123, 142  
Manourova, Anna ... 417,  
447  
Manturano Perez, Ruben  
..... 430  
Manurung, Gerhard .. 279  
Manyengavana, Douglas  
..... 195  
Marin, Monica Paula 356  
Marohn, Carsten 24, 132,  
135, 249, 252,  
254, 255, 258  
Marschner, Bernd ... 123,  
142  
Marthy Tetteh, Francis  
..... 128  
Martini, Endri .. 281, 282  
Martínez, Deissy .... 172  
Marwa, Leonard ..... 402  
Mason, Melanie ..... 24  
Matias, Denise Margaret  
..... 304  
Matofari, Joseph .... 336  
Maurer, Martin ..... 533  
Mausch, Kai ..... 450  
Mawarni, Lisa ..... 214  
Mazancova, Jana .... 535  
Mboh, Cho Miltin ... 161  
Mbugua, Mercy Wanjiru  
..... 309  
Mbugua, Nyori Jeremiah  
..... 313, 469  
Mbugua, Samwel .... 427  
Mburu, John ..... 288  
Mbwana, Hadijah ... 422  
McDonald, Morag ... 114  
McMullin, Stepha ... 421  
Md Saleh, Rosalizan . 403  
Mehmood-Ul-Hassan,  
Muhammad  
..... 287  
Meier, Matthias ..... 180  
Meinhold, Kathrin .. 313,  
446, 469  
Melo, Patrícia ..... 31  
Mendakor Shabong,  
Reuben .... 40  
Menezes, Daniel Ribeiro  
..... 373  
Mengistu, Tilahun Woldie  
..... 102  
Mentler, Axel ..... 136  
Merbold, Lutz . 173, 351,  
368, 369, 374,  
375  
Merckx, Roel ..... 249  
Merdes, Daniel ..... 43  
Meroni, Michele .... 331  
Mesia Rojas, Nicolas Jose  
..... 522  
Mettenleiter, Thomas C.  
..... 42  
Mewa, Eunice ..... 391  
Mewes, Alexander ... 491  
Meyer, Catherine 138, 412  
Meyers, Steve ..... 400  
Meyfroidt, Patrick .... 57  
Mgeni, Charles Peter 511  
Miah, Giashuddin ... 273  
Mibus-Schoppe, Heiko  
..... 399  
Michalscheck, Mirja . 397  
Michels, Thierry .... 197  
Midega, Charles ..... 308  
Mieves, Esther ..... 315  
Mijatovic, Dunja ..... 40  
Millas, Reneth ..... 216  
Milz, Joachim ..... 80  
Min, Akary ..... 485  
Mirzabaev, Alisher .. 512  
Miyingo, Emmanuel  
Wokulira . 386  
Mkomwa, Saidi ..... 133  
Mlotha, Vincent ..... 553  
Mnene, William ..... 333  
Mnimbo, Tatu ..... 457  
Mobarghaee Dinan,  
Naghme h . 441  
Moe San, Aye .. 454, 463  
Möller, Rico ..... 193  
Moenickes, Sylvia ... 533  
Möseler, Bodo ..... 23  
Mössinger, Johannes . 265  
Mofolo, Sifo ..... 553  
Mogha, Neema ..... 23  
Mohamed, Elagba ... 334  
Mohammadzadeh, Arash  
..... 196  
Mokoka, Vincent .... 116  
Mollafilabi, Abdollah 543



- Mollee, Eefke ..... 114  
 Mollel, Richard ..... 353  
 Momani Shaker, Mohamed  
 ..... 358  
 Mondal, Md Alam Hossain  
 ..... 251  
 Monemian, Seyed-  
 mahmoud 541  
 Monfared, Nozar .... 542  
 Montag, Till ..... 62  
 de Moor, Thibault ... 397  
 Morales Velasco, Sandra  
 456, 461, 471,  
 472  
 Moreira Dantas, Ianna  
 Raissa .... 151  
 Moreta, Danilo ..... 141  
 Morgan, Seth ..... 272  
 Moshood, Bakare ... 426  
 Mosnier, Aline ..... 263  
 Mosquera, Silvio Andrés  
 ..... 471, 472  
 Motaghikha, Khatereh  
 ..... 166  
 Mottes, Charles ..... 198  
 Moualeu, Agnès Flore  
 ..... 385  
 Movahedi, Zahra .... 536  
 Mpenda, Zena T. .... 511  
 Mpouam, Serge Eugène  
 ..... 367  
 Mrabet, Farah ..... 387  
 Mshenga, Patience .... 67  
 Muchiri, Steve ..... 88  
 Muchugi, Alice ..... 286  
 Müller, Adrian ..... 180  
 Müller, Andreas ..... 42  
 Müller, Joachim . 89, 107,  
 387, 401  
 Muendo, Kavoi Mutuku  
 ..... 469  
 Mugendi, Daniel .... 129  
 Mugisha, Johnny 424, 440  
 Muhire, Alexandre .. 436  
 Mukanga, Mweshi .... 87  
 Mukundi, John Bosco  
 ..... 115, 469  
 Mulyoutami, Elok ... 281  
 Munini, Bernice ..... 249  
 Munteanu, Melania Florina  
 ..... 356  
 Muoni, Tarirai ..... 254  
 Mupfurutsa, Isabel .. 195  
 Mureithi, Stephen ... 324  
 Muriira, Gacheri .... 286  
 Muriuki, Anne ..... 129  
 Murtaza, Saeed ..... 370  
 Muskat, Linda ..... 85  
 Mussa, Essa Chanie . 512  
 Mustafa, Ayman ..... 334  
 Mutabazi, Khamaldin Daud  
 . 422, 425, 457  
 Mutebi, Samuel ..... 22  
 Mutegi, Charity ..... 89  
 Mutemi, Mary ..... 272  
 Muthini, Davis ..... 414  
 Mutiso, Festus ..... 286  
 Mutota, Emily ..... 489  
 Muys, Bart ..... 101  
 Muzafarova, Albina . 329  
 Muñoz Quiceno, Jhon Jairo  
 456, 461, 471,  
 472  
 Mwambo, Francis Molua  
 ..... 65  
 Mweke, Allan Ndua .. 95  
 Mwema, Catherine .. 438  
 Mwinuka, Lutengano 398  
 Mwonga, Samuel .... 134  
 Myint, Theingi ..... 465
- N**
- Naab, Jesse B. . 256, 260,  
 262  
 Naah, John-Baptist S. N.  
 ..... 332  
 Nabel, Moritz ..... 162  
 Nadiope, Gideon .... 372  
 Nafees, Muhammad . 244  
 Nafi, Eeusha ..... 256  
 Nagle, Marcus ..... 89  
 Naikoba, Diana ..... 306  
 Nairat, Fathi ..... 342  
 Nambafu, Godfrey ... 134  
 Namugalu, Maureen . 184  
 Nangia, Vinay ..... 563  
 Narvaez Vallejo, Alejandra  
 ..... 48  
 Nascimento, Eduardo  
 Michelon ... 366  
 Nascimento, Willian  
 Gonçalves 366  
 Nasiri Dehsorkhi, Abbas  
 ..... 544  
 Nassal, Dinah ..... 164  
 Nassl, Michael ..... 111  
 Natarajan, Mathimaran  
 ..... 153  
 Naumann, Marcel ... 418  
 Nayak, Devashree ... 273,  
 276  
 Ndah, Hycenth Tim . 133,  
 294, 353  
 Ndambi, Oghaiki Asaah  
 ..... 150  
 Ndung'u, Patricia .... 333  
 Ndung'u, Phyllis .... 374  
 Nebié, Baloua ..... 217  
 Nehren, Udo ..... 36  
 Neuhoff, Daniel 181, 184,  
 194  
 Neumann Andersen,  
 Mathias .. 109,  
 122, 131, 384  
 Neumann, Günter ... 152,  
 156  
 Nga, Do Thi ..... 473  
 Ngendo, Mary ..... 421  
 Ngeno, Jonah ..... 73  
 Ngetich, Felix ..... 129  
 Ngo Njiki, Marie Gaelle  
 ..... 61

- Ngunga, David ..... 402  
 Nguyen, Hoang Khanh  
     ..... 159  
 Nguyen, Hung Anh .. 473  
 Nguyen, Minh Tu ... 492  
 Nguyen, Nhung ..... 340  
 Nguyen, Thanh Thi .. 258  
 Ngwenya, Pamela ... 295,  
     315  
 Nicolae, Carmen Georgeta  
     ..... 356  
 Nicolay, Gian Linard 249  
 Nielsen, Flemming 86, 89  
 Niether, Wiebke ..... 229  
 Nischalke, Sarah .... 510  
 Njapau, Henry ..... 87  
 Njiru, Anthony Maina 469  
 Njogo, Samuel ..... 249  
 Njoroge, Ruth ..... 249  
 Njuguna, Michael ... 309  
 Nkengla, Lilian ..... 90  
 Nkomoki, William .... 54  
 Nkonge, Charles ..... 88  
 Nnamani, Ifeoma .... 360  
 Noguera, Amanda .. 471,  
     472  
 Nohr, Donatus .. 410, 420  
 van Noordwijk, Meine  
     ..... 262  
 Noponen, Martin .... 497  
 Noulekoun, Florent .. 262  
 Nouri, Maman Kassoum  
     ..... 156  
 Ntawuruhunga, Pheneas  
     ..... 426  
 Ntsoane, Makgafele Lucia  
     ..... 404  
 Núñez, Jonathan .... 141  
 Nuppenau, Ernst-August  
     230, 424, 427,  
     440  
 Nurdianti, Risma Rizkia  
     ..... 363  
 Nurmatov, Rustam ... 533  
 Nurtazin, Sabir ..... 532  
 Nwachukwu, Bridget 360  
 Nwankwo, Charles Ikenna  
     ..... 152, 156  
 Nyang'au, Isaac Mbeche  
     ..... 308  
 Nyberg, Gert ..... 324  
 Nziguheba, Generose 135  
 Nzogela, Beatus ..... 353
- O**
- Oberson, Nathalie ... 307  
 Odour Odhiambo, Francis  
     ..... 413  
 Oduol, Judith ..... 272  
 Öborn, Ingrid ..... 254  
 Ogolla, Jackline Akinyi  
     ..... 400  
 Ogunsakin, Ayotunde  
     Oluseun .. 354  
 Ogutu, Chris-Ackello 288  
 Ogutu, Sylvester .... 555  
 Okoth, Michael . 391, 400  
 Olajide, Emmanuel ... 92  
 Olaosebikan, Deborah 90,  
     426  
 Oli, Bishwa Nath ... 273  
 Oliveira, Déborah .... 31  
 Olojede, Adeyemi ... 186  
 Olugosi, Olayemi ... 378  
 Olusegun, Christiana 193  
 Omar Adam Guma, Yahia  
     ..... 469  
 Omondi, Monica A. . 115  
 Onasanya, Omolara .. 186  
 Ondiek, James ..... 374  
 Oni, Adebayo ..... 354  
 Onwonga, Richard Ndemo  
     ..... 145  
 Onyango, Alice ..... 362  
 Onyango, Arnold .... 377  
 Onyekwere, Innocent 186  
 Onyuka, Enos ..... 134  
 Oosting, Simon ..... 460  
 Opiyo, Arnold M. ... 392  
 Opoku, Andrews .... 128  
 Oppong Danso, Eric . 109  
 Ordoñez, Jenny ..... 50  
 Orina, Justin ..... 115  
 Ortega, Luis ..... 172  
 Osakwe, Isaac ..... 360  
 Osorio, Ana Milena .. 172  
 Osuga, Isaac ..... 355  
 Otieno, David ..... 335  
 Otinga, Abigael ..... 249  
 Otter, Verena ..... 448  
 Otunchieva, Aiperi .. 539  
 van Oudenhoven, Frederik  
     ..... 565  
 Ouedraogo, Mahama. O.  
     ..... 205  
 Oumarou, Hannatou  
     Moussa .. 156  
 Ousmane, Boukar ... 163  
 Owino, Willis Omondi  
     ..... 469
- P**
- Paganini, Nicole 314, 518,  
     550  
 Palikhey, Epshta ..... 40  
 Paluashova, Gaucharay  
     ..... 540  
 Pantha, Kalyan ..... 213  
 Pantha, Ram Hari ... 273  
 Pantha, Sumitra ..... 213  
 Pardo Villegas, Pedro  
     Daniel 26, 522  
 Parkes, Elisabeth Y. .. 426  
 Parvin, Mst. Tania ... 520  
 Pataczek, Lisa ..... 241  
 Patel, Anant .. 82, 84, 85,  
     168  
 Patt, Nicolas ..... 513  
 Paul, Birthe ..... 353  
 Paul, Namita ..... 90  
 Paulo, Antonio ..... 550  
 Paulos, Helen Berga . 231

Pauly, Alain . . . . .	21	Pulleman, Mirjam	. . . . . 24, 126, 130, 132, 137	Rao, Idupulapati . . . . .	141
Pawelzik, Elke . . . . .	415, 418	Puppala, Jagdeesh Rao	. . . . . 276	Rasch, Sebastian . . . . .	484
Pawera, Lukas . . . . .	32, 430	Pushpakumara, A.W.S.	. . . . . 174	Rasche, Frank . . . . .	135, 141
Pawolka, Marcelli Wiktor	. . . . . 533	Puteri, Jasmine . . . . .	263	Rasoolzadeh, Reihaneh	. . . . . 441
Paz, Liliana . . . . .	172	Pyhälä, Aili . . . . .	52	Rathsack, Ralf . . . . .	187
Pelster, David . . . . .	173	Pypers, Pieter . . . . .	186	Ratinger, Tomas . . . . .	535
Perdana, Aulia . . . . .	283	<b>Q</b>		Rattunde, H. Frederick W.	. . . . . 217
Pereira, Mariana . . . . .	239	Qaim, Matin . . . . .	414, 428, 555	Raut, Manita . . . . .	523
Perez Grovas, Ricardo	Romero . . . . . 406	Qiu, Chen . . . . .	106	Razafindrazaka, Ando	Lalaina . . . . . 208, 209
Perrousset, Emilie . . . . .	521	Quadt, Alexander . . . . .	38	Reddy, M.K. . . . .	212
Peters, Michael . . . . .	364, 456, 461	Quive, Samuel . . . . .	550	Rehman, Irfanur . . . . .	370
Pham Thi Thanh, Nga . . . . .	482	Quiñones, Stefanny . . . . .	471, 472	Reiber, Christoph . . . . .	327
Pham, Tien Duc . . . . .	136	<b>R</b>		Reif, Constance . . . . .	422
Pieters, Alejandro . . . . .	207	Rabitz, Alena . . . . .	136	Rekik, Mourad . . . . .	341
Plagemann, Julian . . . . .	367	Raghavan Sathyan,	Archana . . . . . 53, 482	Renaud, Fabrice . . . . .	492
Plauborg, Finn . . . . .	109	Rahmann, Gerold . . . . .	190, 330	Restrepo Rodriguez, Maria	Jose . . . . . 295
Ploeger, Angelika . . . . .	539	Rajabov, Toshpulot . . . . .	28	Restum Hissa, Helga . . . . .	66
Pochert, Sebastian . . . . .	138	Rajanna, Divya . . . . .	445, 455	Reyes-Agüero, Juan	Antonio . . . . . 36
Pogurschi, Elena Narcisa	. . . . . 356	Rajaona, Arisoa . . . . .	203, 208, 209, 211	Rhyner, Jakob . . . . .	482
Pohl, Alex . . . . .	249	Rajonandraina, Toavintsoa	. . . . . 204	Ribeiro, Maria Margarida	. . . . . 33
Pokhrel, Suroj . . . . .	273	Rakotoson, Tovohery . . . . .	203, 204	Richter, Uwe . . . . .	59
Pole, Mwamuye . . . . .	313	Ramarolahy, Jemima	Amielle . . . . . 203	Riedel, Simon . . . . .	419
Polesny, Zbynek . . . . .	32, 430, 533	Ramos, Fernando . . . . .	263	Rijanta . . . . .	189
Popa, Dana Catalina . . . . .	356	Ranaweera, Bandula . . . . .	167, 174	Rimberia, Fredah Karambu	. . . . . 115, 469
Porembski, Stefan . . . . .	21, 193	Randrianarison, Narilala	. . . . . 474	Ringler, Claudia . . . . .	231, 251, 503
Prabhu, Ravi . . . . .	271, 278	Range, Berndt Krischan	. . . . . 339	Rischkowsky, Barbara Ann	. . . . . 341
Pradilla, Gonzalo . . . . .	490	Rao, Idupulapati . . . . .	141	Rivera, Raúl . . . . .	365
Prasetyo, Pandam . . . . .	284	Rasch, Sebastian . . . . .	484	Rizvi, Javed . . . . .	273, 276
Pretzsch, Jürgen . . . . .	305, 522, 533	Rasche, Frank . . . . .	135, 141	Roba, Hassan . . . . .	377
Pribyl, Ondrej . . . . .	417, 447	Rasoolzadeh, Reihaneh	. . . . . 441	Robinson, Sarah . . . . .	329
Probst, Lorenz . . . . .	133, 294, 443	Rathsack, Ralf . . . . .	187	Rodas, Aldo . . . . .	504
Przyklenk, Michael . . . . .	84, 85	Ratinger, Tomas . . . . .	535	Rodrigues de Lima, Patrícia	. . . . . 373
Pucher, Anna . . . . .	205, 220	Rattunde, H. Frederick W.	. . . . . 217	Rodrigues, Paulo . . . . .	133, 294
Puerta Rodriguez, Cristhian	David . . . . . 456, 461	Raut, Manita . . . . .	523		

- Rodrigues, Thalyane . 366  
Rodríguez García, Virginia  
..... 57  
Rodríguez, Alberto Tarraza  
..... 40  
Röhlig, Anna ..... 424  
Rößler, Regina . 339, 367  
Rojas Lara, Teresa .... 43  
Rollo, Alexandr ..... 33  
Romero Rubiano, Maria  
Fernanda . 406  
Romero, Miriam .... 310  
Rosegrant, Mark .... 503  
Rosenstock, Todd ... 248  
Roshetko, James .... 279,  
281, 282, 284  
Rostami, Majid ..... 536  
Roudart, Laurence ... 505  
Rudenko, Inna ..... 538  
Rudolf, Katrin ..... 310  
Ruediger, Andrea .... 37  
Rugalabam, Jacqueline  
..... 402  
Ruiz, Lisbeth Rocio . 456,  
461  
Ruppel, Silke ..... 168  
Ryan, Casey ..... 60  
Rybak, Constance ... 338,  
425
- S**
- Sabi, Edward Benjamin  
..... 109  
Sadiev, Farkhad .... 540  
Saikia, Panchali .... 523  
Sainz-Sanchez, Pedro Alan  
..... 362  
Saito, Kazuki ..... 203  
Sakdapolrak, Patrick 485,  
506  
Salako, Felix ..... 186  
Salazar-Cubillas, Khaterine  
..... 362, 365  
Salehi, Ali ..... 166  
Salimi, Maedeh ..... 40  
Sallam, Omar ..... 357  
Salman, Muayad .... 342  
Salvatierra, Ana .... 387  
Sam Kofi, Ebenezer . 165  
Samadhi, Nirata .... 263  
Sander, Bjoern Ole .. 227  
Sandhage-Hofmann,  
Alexandra 144  
Sanglestsawai, Santi . 449  
Sanjak, El Amin 313, 469  
Sanogo, Moussa D. . 205  
Santana, Aline da Silva  
..... 373  
Sarfo, Jacob ..... 415  
Sariyev, Orkhan .... 502  
Sarpong, Daniel .... 109  
Sarr, Ibrahima ..... 83  
Sarymsakov, Zakirhodja  
..... 533  
Sattar, Abdul ..... 370  
Sattler, Dietmar ..... 66  
Sattler, Felix ..... 220  
von Saurma-Jeltsch, Ann-  
Kristin ... 468  
Schaffert, Angela .... 240  
Schafleitner, Roland . 241  
Schappert, Alexandra 240  
Schauer, Mark ..... 271  
Scheidegger, Urs 307, 436  
Schelchen, Anja 314, 518,  
550  
Schellberg, Jürgen .... 64  
Schepp, Claudia .... 139  
Schlecht, Eva ..... 244,  
339, 352, 367–  
369, 493  
Schlindwein, Izabela . 338  
Schlossarek, Jan .... 533  
Schlüter, Sabine .... 343  
Schmidt, Kristina Maria  
..... 42  
Schmidt, Matthias .. 550  
Schmidt-Heydt, Markus  
..... 88  
Schmidt-Vogt, Dietrich  
..... 533  
Schmitt, Bastian .... 400  
Schmitt, Christine ... 105  
Schmitter, Petra .... 235  
Schneider, Monika ... 80,  
229  
Schneider, Pia ..... 227  
Schneidewind, Ulf ... 229  
Schrey, Silvia ... 162, 171  
Schreyer, Felix ..... 191  
Schröter, Barbara ... 306,  
507  
Schucknecht, Anne .. 331  
Schüring, Martin .... 469  
Schuler, Johannes ... 133,  
294, 353  
Schurr, Ulrich ..... 162  
Schwake-Anduschus,  
Christine .. 88  
Sebesvari, Zita ..... 492  
See, Linda ..... 263  
Seepai, Apichart .... 379  
Seghatoleslami, Moham-  
madjavad . 564  
Seidel, Anna ... 345, 346  
Seifert, Philipp ..... 352  
Seki-Annan, Ephraim  
..... 234  
Selbmann-Lobbedey,  
Kirsten ... 113  
Seliger, Roman ..... 66  
Sellitti, Stefania .... 439  
Sembène, Mbacké .... 83  
Senthilkumar, Kalimuthu  
181, 184, 194,  
203, 208, 210,  
211  
Seppelt, Ralf ..... 524  
Sererya, Ogossy Gasaya  
..... 285, 405  
Sewchuran, Suren ... 550



- Thellmann, Kevin .... 51  
 Theuvsen, Ludwig ... 393  
 Thevs, Niels ... 270, 277,  
 532, 533  
 Thiel, Andreas ..... 480  
 Thiel, Michael ... 48, 530  
 Thiemann, Irabella .. 124  
 Thomas, Frank ..... 270  
 Thuan, Ngo Thi ..... 473  
 Tilahun, Seifu ..... 235  
 Tischbein, Bernhard . 234,  
 531  
 Tittonnell, Pablo ..... 50  
 Tokula, Mark ..... 186  
 Toloanahary, Solofo Sam-  
 batra ..... 474  
 Tordo, Noel ..... 42  
 Torres Toledo, Victor 387  
 Torres-Gutiérrez, Roldán  
 ..... 154  
 Touhami, Najim ..... 88  
 Touré, Abocar ..... 217  
 Tovihoudji, Pierre G. 169  
 Towett, Erick ..... 274  
 Tran, Cuong ..... 340  
 Tran, Vien Duc ..... 258  
 Trejo Lizama, Wilberth  
 ..... 352  
 Triebel, Andreas .... 469  
 Triller, Sarah ..... 420  
 Troupin, Cécile ..... 42  
 Tsiboe-Darko, Antoinette  
 ..... 316  
 Tsivelikas, Athanasios 27,  
 28  
 Tu, Binh Minh ..... 136  
 Tumbo, Siza ..... 259  
 Tunje, Joseph G. .... 313  
 Twinamasiko, Julius . 138
- U**
- Uckert, Götz ... 133, 285,  
 405  
 Uder, Michelle ..... 48
- Udomkun, Patchimaporn  
 ..... 86, 89  
 Ueberschär, Bernd ... 553  
 Uksa, Marie ..... 164  
 Ul Haq, Shams . 454, 463  
 Ulrichs, Christian 95, 392  
 Urassa, Justin Kalisti 457  
 Urioste Daza, Sergio  
 Alejandro 317
- V**
- Vafabakhsh, Javad ... 196  
 Vagen, Tor-Gunnar .. 272  
 Vajen, Jelana ..... 105  
 Valdo, Stella Cristina Dias  
 ..... 74  
 Valeta, Joshua ..... 553  
 Van Assche, Kristof . 483  
 Van Damme, Patrick 170,  
 417, 447  
 Van der Horst, Dan ... 60  
 Van Dijk, Han ..... 50  
 Van Etten, Jacob .... 302  
 Van Minh, Nguyen .. 473  
 Vandamme, Elke .... 203  
 Vanlauwe, Bernard ... 86,  
 89, 186  
 Vargas, Jorge ..... 365  
 Varnaseri Ghandali, Vida  
 ..... 544  
 Vaz da Silva, Suelene 100  
 Vazquez, Eduardo ... 126,  
 137  
 Verchot, Louis ..... 276  
 Verner, Vladimir 447, 533  
 Vetterlein, Doris .... 152  
 Vicente, Pedro ..... 439  
 Vidal, Stefan ..... 82, 84  
 Viehmannová, Iva .... 34  
 Villamor, Grace .... 238  
 Villegas Panduro, Pablo  
 Pedro .... 430
- Vivas Quila, Nelson José  
 456, 461, 471,  
 472  
 Vlek, Paul L. G. .... 260  
 Vogt, Joachim ..... 58  
 Von Wehrden, Henrik 304  
 de Vries, Marion .... 150
- W**
- Wabwire, Ronald .... 372  
 Wagner, Sigrun ..... 140  
 Wagner, Sven ..... 26  
 Wahome, R.G. .... 145  
 Waing, Frodie ..... 221  
 Wairore, John ..... 324  
 Wakkumbure, Lal .... 40  
 Wald, Julian Philipp . 410,  
 420  
 Walsh, Markus G. ... 274  
 Walte, Hans-Georg ... 88  
 Walz, Henriette ..... 55  
 Wander, Alcido Elenor  
 ..... 160  
 Wang, Xialin ..... 230  
 Wangaruro, Jane .... 249  
 Warta, Zulfra ..... 263  
 Warth, Benjamin .... 252  
 Wasonga, Oliver . 59, 325,  
 333, 335  
 Wassie, Shimels 362, 368,  
 369  
 Wassmann, Reiner .. 183,  
 185, 227  
 Waswa, Lydiah ..... 427  
 Watson, Conor ..... 127  
 Watson, Liz ..... 478  
 Watt, Michelle ..... 171  
 Webber, Heidi ..... 256  
 Webster, Emily .. 24, 130  
 Wedig, Karin ..... 328  
 Weerakkody, W.J.S.K.  
 ..... 174  
 Weissshaidinger, Rainer  
 ..... 249
- 581



# Index of Keywords

## A

- Abiotic stress 82, 168, 215  
Abscisic acid ..... 34  
Abundance ..... 21, 332  
Access ability ..... 458  
Actors ..... 250, 474  
    network theory . 496  
*Adansonia digitata* .. 313,  
    446, 470  
Adaptation 195, 490, 496,  
    505, 516, 524  
    strategies ..... 532  
Adaptive  
    capacity ..... 53  
    management .... 41  
Adequate household food  
    ..... 318  
Adoption 25, 54, 63, 151,  
    294, 450  
    barriers ..... 103  
    constraints . 133, 353  
    decision ..... 312  
Advisory services ... 297  
Aerial image ..... 56  
Afghanistan ..... 63, 565  
Aflatoxin ..... 86–89  
African  
    indigenous vegetables  
        192, 296, 392,  
        455  
    nightshade . 76, 399  
    spinach ..... 76  
    yam bean ..... 371  
Aggregate stability .. 131  
Agricultural  
    diversification .. 552  
    Agricultural  
        extension .. 309, 414  
        innovation system ...  
            389  
        intensification ... 57  
        mechanisation .. 389  
        policies ..... 436  
        practices .... 87, 487  
        productivity 25, 510,  
            494  
        transformation .....  
            12–14, 478  
    Agro-industrialisation 187  
    Agro-pastoralists .... 324  
    Agrobiodiversity . 20, 41,  
        413, 424  
        conservation ... 458  
    Agroecological practices  
        ..... 314, 518  
    Agroecology ... 135, 197,  
        296, 443, 490  
    Agroecosystems ..... 490  
    Agroforestry ..... 25,  
        56, 101, 132,  
        180, 229, 261,  
        271–273, 276–  
        280, 284, 285,  
        287, 466, 486,  
        529  
        coffee ..... 140  
        concession ..... 522  
        extension ..... 282  
        systems 80, 81, 187  
    Alder trees ..... 166  
    Algae ..... 545  
    Alley-cropping ..... 180  
Alternate wetting and  
    drying 203, 227  
Alternative food  
    sources ..... 430  
    systems ..... 443  
*Amaranthus* spp. .... 392  
Amazon ..... 458  
    Peruvian ..... 522  
AMF ..... 163  
Amylase ..... 416  
Animal  
    draught ..... 395  
    nutrition ..... 367  
    source foods .... 338  
    trading ..... 471  
    transport ..... 471  
    welfare ..... 343  
Antinutritional factors 410  
Antioxidant exogenous  
    ..... 214  
Aquaculture 195, 253, 328  
    solar-powered .. 554  
Aral sea ..... 531, 562  
Arbuscular mycorrhiza  
    . 153, 157, 163  
Argentina ..... 237  
*Arnica montana* ..... 32  
Artemisinin ..... 157  
Artificial insemination  
    ..... 342  
*Aspergillus flavus* ..... 88  
Assessment ..... 387  
Asset  
    accumulation .. 272  
    building ..... 504  
    ownership ..... 457



- Astragalus polysaccharides* ..... 376
- Attract-and-kill ..... 84
- Awareness ..... 86, 426
- Azospirillum brasilense* ..... 160
- B**
- Bacterial leaf blight .. 221
- Baculovirus ..... 93
- Bamboo ..... 104, 486
- Banana ..... 72, 79
- BBTD ..... 90
- processing ..... 108
- waste ..... 108
- Bangladesh 297, 520, 523
- Baobab ... 115, 313, 446, 470
- Bayesian ..... 274
- modeling ..... 248
- networks . 275, 289, 484
- Bees ..... 21, 27
- Beneficial insects ..... 91
- Benin ..... 169, 558, 559
- Big push ..... 303
- Biochar ... 110, 122, 123, 174, 384, 398
- compost ..... 142
- Biocontrol ..... 84
- Biocultural
- diversity ..... 39
- landscapes ..... 41
- Biodiversity ... 311, 332, 410, 412
- Bioeconomy 99, 105, 112, 113, 534
- Bioenergy . 108, 111, 278
- Biofertilisation ..... 168
- Biofertiliser 100, 153, 159
- Biofortification . 206, 426
- Biofuels ..... 101, 278
- Biogas 103, 107, 108, 159
- Biogenous element .. 545
- Bioirrigation ..... 153
- Biological
- control ..... 83, 92
- agents ..... 84
- crop protection .. 82
- invasions ..... 72
- nitrification inhibition ..... 126
- nitrogen fixation 155
- preparations ... 540
- Biomass 65, 193, 386, 406
- energy use ..... 106
- potentials ..... 111
- uses ..... 102
- Biopesticide ..... 95
- Bioplastics ..... 112
- Biosphere reserve ... 116, 538
- Bitter kola ..... 417
- BNI ..... 141, 155
- Bootstrapping ..... 53
- Borana ..... 377
- Borneo ..... 43
- Brachiaria*
- brizantha* ..... 130
- grasses ..... 126
- Bracon hebetor* ..... 83
- Brazil ..... 239, 278
- dairy sector .... 393
- savannah ..... 242
- seasonal dry forest .. 31
- Broiler
- carcass ..... 357
- quality ..... 361
- performance .... 357
- starter ..... 360
- Buffalo ..... 370
- milk ..... 370
- Bullocks ..... 397
- Burkina Faso .... 21, 193, 367, 505
- Bush encroachment .. 144
- Business activities ... 480
- Butter ..... 400
- C**
- Caatinga ..... 327
- Cabinet drying ..... 391
- Cacao ..... 80, 191
- agroforestry systems 26
- Cacopsylla picta* ..... 85
- Calophyllum ..... 278
- Calotropis procera* .. 286
- Cambodia ..... 521
- smallholders ... 345, 346
- Camel ..... 334, 336, 377
- milk powder .... 400
- Capacity
- building .... 42, 105
- development .. 287, 554
- Capitalism ..... 508
- Capsicum annum* ... 361
- Carbohydrate mobilisation ..... 207
- Carbon ..... 258
- balance ..... 207
- discrimination . 241
- neutral ..... 140
- losses ..... 142
- sequestration .... 24, 109, 140, 180, 272, 441
- Carotenoids ..... 404
- Cassava ..... 186, 426
- by-products .... 107
- diet ..... 371
- disease ..... 72
- intercropping ... 186
- root peeling .... 401
- starch processing 107
- Catchments ..... 59
- Cattle 330, 362, 367–369, 374
- productivity .... 345

- Cattle  
  production 461, 464, 471  
  sub-maintenance  
    feeding ... 375  
Causal chain ..... 272  
Cayenne pepper ..... 361  
Central Africa ... 89, 417  
Central America . 25, 406  
Central Asia ... 277, 329, 534, 538  
Certification . 78, 79, 435, 467  
Chad ..... 307  
Chain governance ... 455  
Chemical  
  composition 363, 379  
  of soils ..... 540  
  fertilisation ..... 172  
Chicken meat ..... 388  
Chickpea ..... 145  
Child schooling ..... 512  
Childhood work ..... 512  
Chilling model ..... 290  
Climate  
  chambers ..... 193  
  change ..... 43, 55, 72, 193–195, 251, 255, 262, 290, 479, 493, 516, 539, 548  
  adaptation ... 180, 191  
  mitigation ..... 311  
  scenarios ..... 260  
  smart agriculture  
    ..... 497  
  variability . 490, 506  
  vulnerability .... 53  
Cluster analysis . 462, 519  
Co-benefits ..... 311  
Co-opetition ..... 446  
Co-inoculation ..... 160  
Cobs ..... 398  
Cocoa ..... 187, 466, 497  
Cocoa  
  farmers ..... 481  
  intensification ... 81  
  pod husk ..... 378  
Coffee  
  agroforestry .... 140  
  certifications ... 435, 439  
Cold stress ..... 209, 210  
Coliform bacteria .... 472  
Collaborative management  
  ..... 495  
Collective action 237, 495  
Colombia ..... 78  
Combining ability ... 216  
Commercialisation ... 67, 442, 446, 450  
Commodity chain frame-works .... 496  
Common  
  bean ..... 74, 155  
  interest groups . 309  
  property resource  
    ..... 233, 237  
Communication 297, 299, 538  
  analysis ..... 305  
Community  
  based participatory  
  approach . 413  
  forestry ..... 504  
Competitiveness 257, 456, 461  
Complementary foods 416  
Compost .. 142, 167, 174, 505, 536  
Conceptual model ... 238  
Conflicts ..... 494  
  upstream-down-  
  stream .... 532  
Connecting knowledge  
  ..... 250  
Conservation ..... 20, 52  
  agriculture ..  
    133, 178, 294, 521  
  Consumption .....  
    expenditure .... 272  
    patterns .. 338, 411, 514  
  Contextual ..... 516  
  Contract farming 473, 508  
  Conventional management  
    system ... 441  
  Cooking ..... 398  
    stoves 285, 384, 405  
    test ..... 285  
  Cool farm tool ..... 172  
  Cooperation .... 558–560  
  Cooperative farmers . 535  
  Coordinated value chains  
    ..... 455  
  Coping ..... 524  
    strategy index .. 318  
  Coralling ..... 128  
  Cost  
    benefit analysis 150, 532  
    of diet ..... 415  
  Costa Rica ..... 140  
  Cotton ..... 193, 563  
  Cowpea ..... 73, 163  
  Crop  
    coefficient ..... 563  
    conservation ..... 39  
    -land allocation stra-  
    tegy ..... 535  
    mapping ..... 64  
    model ..... 161, 289  
    nutrition ..... 536  
    production . 260, 412  
    residue .... 172, 178  
    management . 256  
    rotation ..... 48, 244  
    water requirement ...  
      259

- Cropping  
  intensity ..... 184  
  systems ..... 35, 76  
CROPWAT model ... 259  
Croton ..... 278  
Crowdsourcing ..... 264  
Crown volume ..... 80  
CSM-CERES ..... 260  
Cultural ..... 516  
  memory ..... 39  
  centric narratives  
    ..... 301  
Customary land tenure 49
- D**
- Dairy ..... 351, 460  
  cattle ..... 337  
  cooperatives .... 393  
  farm . 365, 387, 542  
  processing ..... 341  
  firms ..... 393  
  product ..... 89  
  quality ..... 341  
Dam construction ... 288  
Data envelopment analysis  
  ..... 65  
Date palm ..... 394  
Decision  
  analysis ... 248, 275  
  making ..... 502  
  support tool .... 186  
Decomposition ..... 145  
Deficit irrigation 240, 241  
Degradation . 58, 66, 138,  
  264, 276  
Desertification ..... 136  
Desiccation cracks ... 124  
Desorption ..... 122  
Detheobromination .. 378  
Diagnostic assays ..... 42  
*Diaphorina citri* ..... 91  
Diet diversity ..... 410
- Dietary  
  diversity .. 412–414,  
    419, 424, 425,  
    427  
  choices ..... 428  
  sodium diformate  
    ..... 359  
Digestibility ... 354, 368,  
  369, 374, 375  
Discrete choice  
  experiment .... 521  
  modeling ..... 454  
Dissemination .. 297, 551  
Disturbance impacts . 252  
Diversification .. 21, 179,  
  197, 279, 548  
DNA ... 33, 127, 164, 544  
Domestication  
  ..... 281, 286, 417,  
  469, 487, 529  
Dormant alfalfa ..... 365  
Dose-response experiment  
  ..... 171  
DR Congo ..... 487  
Dried beef ..... 391  
Drip irrigation ..... 521  
Drought ..... 132, 485  
  adaptation ..... 327  
  hazard monitoring  
    ..... 64  
  stress ..... 214  
Drying ..... 386, 403  
  meat ..... 377, 391  
  model ..... 403  
Drylands ... 50, 136, 324,  
  325  
DSSAT modeling .... 563  
Dung patches ..... 173  
Dye tracer ..... 124  
Dynamics of change 197,  
  238
- E**
- Ear headminer ..... 83
- Earthworms ..... 130  
East Africa .. 22, 23, 194,  
  208, 275, 289,  
  296, 328  
Ebola virus ..... 42  
Eco-functioning ..... 91  
Ecological ..... 496  
  drivers ..... 332  
  modelling ..... 35  
Econometric analysis 459  
Economic  
  development ..... 38  
  efficiency ..... 339  
  experiments .... 233  
  impact ..... 435  
  preferences ..... 488  
Economics ..... 271, 340  
Ecosystem ..... 58  
  based adaptation 479  
  multifunctionality ...  
    116  
  services .. 25, 26, 51,  
    284, 489  
Ecotourism ..... 495  
Edible insects .. 411, 429,  
  430  
Education ..... 444  
Egg  
  quality ..... 358  
  yolk ..... 356  
Egypt ..... 251  
Electron microscopy .. 74  
Elite capture ..... 311  
Emerging  
  economies ..... 448  
  transformations 324  
Emergy ..... 65  
Emission factor ..... 374  
Employment ..... 104  
Empowerment . 295, 300,  
  439, 443, 502,  
  517, 523, 572  
Enclosure ..... 324  
Endophytes ..... 82, 168

- Energy ..... 398, 503  
 balance .... 390, 424  
 efficiency ..... 196  
 security ..... 101  
*Enset* ..... 419  
 Enteric methane ..... 374  
 Entomopathogenic  
 fungi ..... 84, 95  
 microorganisms . 85,  
 430  
 Environmental  
 change ..... 524  
 degradation .... 562  
 governance ..... 458  
 isotopes ..... 236  
 thresholds ..... 51  
 variations ..... 237  
 Enzymatic treatment . 401  
 Enzyme activity ..... 164  
 Erosion ..... 66  
 control ..... 255  
 Ethiopia ... 37, 104, 161,  
 190, 235, 251,  
 298, 305, 308,  
 419, 420, 423,  
 442, 450, 486,  
 502, 506, 510,  
 517, 549, 560  
 Ethnomedicine ..... 32  
 Ethnoveterinary medicine  
 ..... 352  
 European Union ..... 287  
*Ex ante* assessment .. 509  
 Exogenous price changes  
 ..... 106  
 Expert farmer ..... 282  
 Extension .. 86, 102, 280,  
 282, 287, 298,  
 299, 305, 309,  
 310, 313, 414,  
 459, 473, 513,  
 522  
 effectiveness .. 555
- F**  
 Fair trade . 435, 439, 443,  
 449  
 Farm  
 employment .... 510  
 typology ..... 179  
 workers ..... 439  
 Farmer  
 collectives 295, 523  
 diversity ... 505, 554  
 field school 282, 436  
 management strate-  
 gies ..... 259  
 preferences .... 307  
 valuation ..... 315  
 Farming  
 expansion ..... 59  
 systems ... 460, 487  
 Farmyard manure ... 181,  
 184  
 Fattening ..... 325  
 Fecal sludge .... 167, 174  
 Feed  
 efficiency ..... 362  
 policy ..... 372  
 regulation ..... 372  
 Feeding ..... 366, 402  
 substrates ..... 355  
 Feminisation of agriculture  
 ..... 523  
 Fermentation ..... 416  
 quality ..... 379  
 Fertiliser ..... 186, 398  
 application . 170, 204  
 foliar application ....  
 214, 544  
 microdosing .... 169  
 need ..... 134  
 use efficiency ... 161  
 Fertility ..... 128  
 Fiber ..... 286  
 Field bunding ..... 181  
 Filoviruses ..... 42  
 Firewood ..... 398
- Fish ..... 554  
 Fisheries ..... 195  
 transformation . 253  
 Flash floods ..... 482  
 Flavonoids ..... 399  
 Flood-based farming sys-  
 tems ..... 289  
 Floodplain ..... 181, 484  
 Flora ..... 21, 29, 114  
 Flow paths ..... 124  
 Fodder ..... 286  
 production ..... 560  
 Food ..... 29, 503  
 access ..... 67, 421  
 and nutrition security  
 448, 551  
 consumption score ..  
 318  
 culture ..... 565  
 groups ..... 421  
 insecurity ..... 303  
 loss ..... 392  
 prices ..... 514  
 processing 421, 446,  
 484  
 safety ..... 88, 472  
 security ..... 52,  
 54, 90, 102, 105,  
 111, 194, 275,  
 312, 314, 316,  
 318, 404, 411,  
 427, 467, 470,  
 486, 507, 508,  
 518, 519, 534  
 upgrading strate-  
 gies .....  
 306  
 sovereignty 443, 508,  
 552  
 systems ..... 529  
 value chain ..... 507  
 Forages ..... 345, 346  
 resources ..... 332

Forages  
 technologies ... 353  
 Forecast information . 297  
 Forest ..... 61  
 degradation .... 277  
 enterprises ..... 504  
 transitions ..... 57  
 Forest-based rural develop-  
 ment ..... 534  
 Formal education ..... 27  
*Frankia* symbiosis ... 166  
 French West Indies .. 198  
 Friability ..... 131  
 Fruits ..... 115  
 exports ..... 448  
 trees ..... 290, 534  
 Fungal contamination . 88  
 Fungi ..... 89  
 Future  
 agriculture 105, 486  
 uncertainty .... 232

**G**

Gastronomy ..... 39  
 GCA effect ..... 216  
 Gender ... 103, 179, 238,  
 402, 457, 504,  
 516, 523  
 dynamics .. 90, 513  
 role ..... 281, 316  
 Gene banks ..... 20, 202  
 Genetic  
 control ..... 74  
 diversity ... 73, 218,  
 219, 541  
 resistance ..... 76  
 resources ..... 37  
 structure ..... 33  
 Genome sequencing . 202  
 Genotypes ..... 210, 426  
 Geostatistics ..... 56  
 Ghana 110, 142, 191, 243,  
 266, 437, 481,  
 497

GHG emissions . 173, 285  
 GIS ..... 277, 537  
 Global warming ..... 196  
*Globodera* ..... 76  
 Glucose ..... 401  
 Goat husbandry . 128, 327,  
 337  
*Gongronema latifolium*  
 ..... 360  
 Good agricultural practices  
 ..... 343, 551  
 Governance ..... 305  
 challenges 326, 389,  
 520  
 Grass ecotypes ..... 333  
 Grazing ..... 330, 345  
 Green manure .. 181, 184  
 Greenhouse gas emissions  
 ..... 368  
 Groundnut ..... 87, 188  
 varieties ..... 188  
 Group socialisation .. 299  
 Guatemala ..... 504  
 Guava fruit ..... 418

**H**

Habitat ..... 27  
 distribution . 28, 332  
 Haematology ... 354, 361  
 Harvesting technique 134  
 Hazard  
 mitigation ..... 496  
 prone areas .... 482  
 Hedgerows ..... 261  
 Helminths ..... 352  
 Herbicides ..... 198  
 Heterosis ..... 216, 220  
 Hidden hunger . 205, 275,  
 420, 519  
 Hierarchical linear model  
 ..... 266  
 Hillside agriculture .. 395  
 Holistic  
 assessment .... 234

Holistic  
 modeling ..... 248  
 Homegardens .. 114, 182,  
 275  
 Honey ... 21, 27, 230, 304  
 Honeybees ..... 27  
 Horticulture ... 174, 438,  
 404, 521  
 Household . 106, 398, 480  
 decision making 281  
 dietary diversity 318,  
 423  
 welfare ..... 514  
 Human  
 health disorders . 32  
 migration ..... 506  
 rights ..... 467  
 Hybrid  
 breeding ..... 206  
 crops ..... 217, 508  
 parent lines ..... 221  
 rice ..... 221

**I**

ICP-OES analyses ... 171  
 Impact ..... 55, 272, 518  
 assessment 113, 435  
 Implementation processes .  
 306  
 Improved  
 chickpea ..... 450  
 forages ..... 364  
 stoves ..... 406  
 Incentives . 150, 521, 522  
 Inclusive development  
 ..... 328  
 Income  
 generation ..... 551  
 security ..... 513  
 Index-insurance ..... 481  
 India . 233, 273, 278, 488,  
 523  
 Indicator film ..... 388

- Indigenous**  
 food system .... 430  
 fruit trees ..... 417  
 grasses ..... 333  
 knowledge ..... 301  
 people ..... 52  
**Indonesia** . 150, 189, 310,  
 344, 495  
**Informal institutions** .. 37  
**Information technology**  
 ..... 485  
**Informational intervention**  
 ..... 310  
**Infrastructure development**  
 ..... 189  
*Inga edulis* ..... 33  
**Innovation** 198, 303, 315,  
 387, 558, 559  
 platforms ..... 250  
 processes .. 295, 312  
 system  
 analysis ..... 446  
 approach ... 314,  
 518  
**Insects** ..... 385  
**Institutional**  
 assistance ..... 485  
 innovations ..... 102  
**Integrated systems** ... 239,  
 242, 552, 554  
**Intensification** ..... 484  
**Intercropping** .. 153, 186,  
 183, 257, 405  
**Internationalisation** . 448,  
 456  
**Intra-household decision**  
 ..... 103  
**Intra-species diversity** 541  
**Intrinsic motivation** ... 28  
**Investment** ..... 271  
 viability ..... 288  
**Iran** ..... 40, 63, 166, 196,  
 441, 536, 541–  
 544, 564  
**Iron** ..... 425  
 toxicity ..... 204  
**Irrigation** . 110, 233, 237,  
 288  
 deficit ..... 240, 241  
 gravity ..... 244  
 small scale . 234, 235  
 waste water .... 143  
**Isotope discrimination**  
 ..... 141  
**J**  
**Job creation** ..... 564  
**Jordan Rift Valley** ... 342  
**K**  
**Kales** ..... 145  
**Katuk leaves** ..... 363  
**Kendal's concordance** . 86  
**Kenya** 151, 278, 301, 303,  
 318, 333, 335,  
 412, 414, 424,  
 428, 460, 509,  
 519, 555  
 Central Highlands ...  
 337  
**Kerinci Seblat National**  
**Park** ..... 495  
**Key informant interview**  
 ..... 520  
**Knowledge**  
 management .... 329  
**L**  
**Lactic acid bacteria** .. 379  
**Lagoon of Porto-Novo** 58  
**Lake Naivasha Basin** 232  
**Lake-collector** ..... 545  
**Land**  
 degradation .....  
 23, 35, 136, 262,  
 271, 506, 530  
 management ... 274  
**Land**  
 reclamation condition  
 537  
 restoration ..... 25  
 system sciences .. 57  
 tenure ..... 54  
 transformation ... 30  
**Land use**  
 change . 22, 125, 530  
 transition ..... 230  
 displacement .... 57  
**Landraces** . 205, 213, 218  
**Landsat** ..... 62, 64  
**Landscape** ..... 254  
 approach ..... 284  
 connectivity ..... 30  
 modelling ..... 250  
 resistance values . 30  
 restoration methodol-  
 ogy  
 ..... 264  
**Landslides** ..... 482  
**Latin America** ... 29, 448  
**Laying hens** .... 356, 358  
**Leaching** ..... 540  
**Leaf**  
 area ..... 213  
 onset ..... 62  
**Leafy vegetables** .... 134,  
 423, 549  
**Lean data** ..... 302  
**Least-cost path** ..... 30  
**Legumes** ... 87, 137, 145,  
 241, 254, 257,  
 544  
**Life cycle analysis** ... 112  
**Linear programming** .. 61  
**LINK methodology** .. 466  
**Lintul 5** ..... 257  
**Livelihood** .. 60, 63, 133,  
 195, 279, 280,  
 353, 458, 480,  
 504, 506

- Livelihood  
 benefits ..... 230  
 impact ..... 505  
 strategies ..... 519  
 vulnerability index ..  
 482
- Livestock .. 42, 133, 326,  
 331, 338, 402,  
 456, 532  
 production . 137, 339  
 strategies ..... 337  
 systems ..... 353
- Local  
 community ..... 483  
 food systems ... 443  
 initiatives ..... 539  
 knowledge 138, 280,  
 296, 304, 333  
 markets ..... 458
- Locusts ..... 355
- Lost crop ..... 39
- Low input conditions 217
- Low-quality roughage 368
- Lowland rice ... 210, 211
- Lupin ..... 145
- M**
- Macrofauna ..... 130
- Madagascar ... 202–204,  
 208, 209, 474,
- Maize . 88, 124, 128, 151,  
 161, 165, 169,  
 178, 183, 258,  
 261, 437
- Malawi ..... 55, 446, 553
- Malnutrition ..... 426
- Mango ..... 404, 454
- Mannitol ..... 34
- Manure ... 123, 127–129,  
 158, 169, 181,  
 194, 204  
 management ... 150  
 quality ..... 173
- Market ..... 102, 283  
 access ..... 135, 438  
 chain ..... 447  
 choice ..... 440  
 oriented crops .. 457  
 participation .... 459  
 value ..... 441
- Marketers ..... 437
- Marketing ..... 325  
 cooperatives .... 442
- Matricaria chamomilla* 32
- Meal frequency ..... 423
- Mechanisation ..... 402
- Medicinal plants 32, 447,  
 536
- Medicines ..... 29
- Mediterranean region 290
- Medium-term conservation  
 ..... 34
- Meloidogyne* ..... 76
- Meta-analysis .. 180, 524
- Methane ..... 183  
 sink ..... 125  
 yield ..... 375
- Micro-lysimeter ..... 242
- Microbial mineralisation  
 ..... 164
- Microclimate ..... 239
- Microcredit ..... 520
- Micronutrients .. 155, 420
- Microsatellite locus ... 33
- Migration ... 63, 512, 523
- Milk ..... 88, 89, 334  
 demand ..... 362  
 processing plant 400  
 production cost . 365  
 quality ..... 387  
 yield ..... 351
- Mineral  
 fertiliser .. 151, 159,  
 181  
 nutrition ..... 157
- Minimum dietary diversity  
 ..... 421
- Mining ..... 56  
*Mirabilis expansa* .... 39
- Mixed logit ..... 454
- Modelling ..... 227, 250,  
 253–258
- MODIS ..... 331
- Monitoring ..... 318
- Monoculture .... 80, 229
- Moringa oleifera* .... 38
- Mother-child pairs ... 419
- Mountain futures .... 529
- Mozambique ... 446, 551
- Multi-objective modelling  
 ..... 264, 494
- Multi-stakeholder plat-  
 forms .... 305,  
 464, 466, 468
- Multi-storey cropping sys-  
 tems ..... 182,  
 549
- Multiple water users . 234
- Multipurpose trees ... 182
- Multivariate analysis . 179
- Mungbean ..... 183
- Municipal solid waste 174
- Myanmar . 188, 463, 465,  
 508
- Mycorrhizal symbiosis  
 ..... 126
- Mycotoxin ..... 88
- N**
- Nano-fertiliser ..... 536
- Napier ..... 379
- Natural  
 dyes ..... 388  
 resource management  
 63, 115, 253
- NDVI ... 56, 64, 304, 331,  
 530
- Neem ..... 278, 352
- Nematodes ..... 76, 92
- Nepal . 236, 273, 493, 523
- NERICA ..... 184

- Nestedness ..... 50  
 Net-Map .. 306, 326, 389,  
 507, 520  
 Network modelling .. 253  
 Nicaragua .. 25, 130, 132,  
 439  
 Niger ..... 331  
 Nigeria ... 170, 186, 316,  
 359, 426  
 Nile basin ..... 251  
 Nitrate ..... 139  
 leaching ..... 141  
 Nitrogen .. 155, 258, 369  
 assimilation .... 141  
 fixation ..... 132  
 losses ..... 142  
 partitioning 241, 362  
 split ..... 211  
 supply ..... 159  
 uptake ..... 141  
 use efficiency .. 178,  
 180  
 utilisation ..... 354  
 Nitrous oxide ..... 183  
 Non-farm  
 activities ..... 480  
 employment ... 510,  
 512  
 Non-invasive plant pheno-  
 typing .... 171  
 Non-market value ... 441  
 Non-timber forest products  
 ..... 283, 447  
 Nut trees ..... 290  
 Nutrient  
 acquisition ..... 157  
 availability .... 208  
 cycling .... 127, 185  
 leaching ..... 123  
 release ..... 145  
 residual ..... 165  
 use efficiency ... 196  
 Nutrition .. 355, 404, 410,  
 413, 422, 534  
 Nutrition  
 communication 301  
 education .. 413, 414  
 security ... 314, 518  
 sensitive agriculture  
 . 309, 548, 549  
 Nutritional  
 composition ... 377,  
 418  
 quality .... 346, 552  
 status ..... 419, 427
- O**  
 Oases ..... 394  
 Obesity ..... 428  
 Oil palm ... 61, 170, 310,  
 467  
 On-farm cooling .... 387  
 Opportunity cost 101, 266  
 Optimisation ... 386, 401  
 Orangutan ..... 43  
 Organic  
 acids ..... 359  
 farming 80, 179, 441,  
 443  
 fertiliser .. 150, 162,  
 172  
 pineapple ..... 440  
*Oryza sativa*  
 185, 208, 209,  
 221, 227, 485  
 Osmotic agents ..... 34  
 Overgrazing .... 136, 333  
 Oxytocin ..... 370
- P**  
 P deficiency ..... 203  
 Paddy rice ..... 124, 183  
 Pair-wise comparison 180  
 Pakistan .. 103, 244, 370,  
 454  
 Palestine ..... 342  
 Palm fruit fibre ..... 384  
 Pamir ..... 565  
 Panama ..... 29  
 Panel data ..... 428  
 Panmictic midparent  
 heterosis . 220  
 Parasitisation ..... 94  
 Partial budgeting .... 160  
 Participatory  
 action research . 552  
 design ..... 198  
 guarantee system ...  
 314, 551  
 methods ..... 265  
 outcome evaluation  
 tools ..... 315  
 variety selection 307  
 video ..... 294, 295  
*Passiflora edulis* ..... 79  
 Pastoralism 311, 324, 325,  
 335  
 Pasture ..... 66, 239  
 degradation .... 130  
 management .... 329  
 regrowth ..... 252  
 rehabilitation .... 66  
 Patchy vegetation structure  
 ..... 252  
 Pathogen ..... 75  
*Paubrasilia echinata* .. 36  
 Payment for ecosystem ser-  
 vices . 230, 266  
 PCR ..... 33, 88  
 Pearl millet . 83, 156, 206,  
 220, 259  
 roots ..... 152  
 Peatlands ..... 43  
 Perception . 86, 310, 397,  
 493  
 Performance ... 335, 354,  
 361, 371  
 Peri-urban agriculture  
 . 150, 192, 367  
 Persian oak ..... 541  
 Peruvian Amazon . 26, 33  
 Pest risks ..... 72, 81



- Pesticide . 82, 92, 95, 156, 196, 198  
*Phakopsora pachyrhizi* 75  
*Phaseolus vulgaris* ... 74, 132, 154, 155, 254  
 Phenolics ..... 399  
 Phenology . 62, 209, 210, 215, 331  
 Phosphorus .... 122, 126, 155, 164, 171  
 Photovoice ..... 489  
 Phytochemistry .... 417  
 Pigs ..... 352, 367, 376  
 Pineapple ..... 92, 352  
 Plant  
   communities ..... 22  
   ecology ..... 35  
   functional types . 116  
   growth promoting  
     bacteria ..... 73  
     rhizobacteria . 153  
   interactions ..... 252  
   plasticity ..... 171  
   viruses ..... 78, 79  
 Ploughing ..... 397  
 Policy ..... 179, 273, 422  
   analysis ..... 456  
   implication ..... 336  
   instruments ..... 522  
 Pollination ... 21, 27, 394  
 Poplar ..... 270, 277  
 Population  
   dynamics .... 31, 33  
   hybrids ..... 220  
 Postharvest  
   milk losses .... 336  
   technology .... 404  
 Postpartum ..... 334  
 Potassium ..... 171  
 Potato ... 82, 84, 158, 436  
   diggers ..... 395  
 Poultry ..... 359  
   egg quality ..... 358  
 Poverty ..... 303  
   alleviation . 208, 230, 266, 300, 450, 513  
 Principal component analysis 26, 56, 445, 486, 502  
 Probabilistic simulation ..... 288  
 Probit regression 54, 151, 440, 445, 450  
 Process  
   based modelling 252  
   net-map ... 326, 520  
   optimisation ... 400  
   tracing ..... 272  
 Producers ..... 474  
   organisations ... 442  
 Product development 470  
 Production  
   costs ..... 564  
   diversity ..... 412  
   factors ..... 510  
   function ..... 339  
   networks ..... 458  
 Productivity ..... 190  
 Profit maximisation .. 535  
 Profitability .... 128, 169, 170, 190, 325  
 Progesterone ..... 334  
 Protein use efficiency . 362  
 Proximate composition ..... 378  
 Pseudomonas ..... 472  
 Public policy ... 456, 461  
 Pulses ..... 465  
 Push-pull technology . 85, 308
- Q**  
 Quality  
   factors 377, 418, 543  
   yields ..... 78  
 Quasi-experimental .. 272
- R**  
 Rabbits ..... 371  
 Racehorses ..... 344  
 Rainfall ... 129, 259, 480  
 Rainwater  
   management ... 228  
   use efficiency ... 243  
 Ranching ..... 330  
 Random forest .... 55, 64  
 Randomisation ..... 310  
 Rangelands ..... 331  
   management ... 144, 330  
 Reforestation 43, 266, 466  
 Regional strategy .... 448  
 Rejuvenation ..... 115  
 Remote sensing .. 48, 59, 264, 537  
 Renewable energy .. 100, 542  
 Research-extension systems . 102, 308  
 Residue management 127, 183  
 Resilience ... 25, 41, 228, 271  
 Resource  
   recovery ..... 174  
   reuse ..... 167  
   use efficiency ... 260  
 Rhizobia ... 73, 155, 165, 171  
*Rhizobium* ..... 154, 160  
*Rhizopus stolonifer* .. 378  
 Rhizosphere dynamics ..... 152  
 Rice .. 185, 204, 207, 212, 213, 449, 558, 559  
   hybrid ..... 216, 221  
   landraces ..... 218  
   lowland ... 203, 210, 211  
 NERICA ..... 184

- Rice  
value chain ..... 463
- Ripple effect ..... 273
- Risk ..... 488  
assessment ..... 483  
management .... 483  
perception . 483, 491
- Rock phosphate ..... 163
- Root zone ..... 211
- Rubber plantation . 30, 62,  
125, 255, 345
- Rumination ..... 366
- Rural ..... 422  
areas ..... 488  
development 63, 271,  
300, 491, 505  
livelihoods .. 49, 78,  
106, 490
- Rwanda 67, 208, 211, 436
- S**
- Saffron ..... 196, 543
- Salinisation 127, 492, 540
- Sapflow ..... 270
- Saturniids ..... 429
- SCA effect ..... 216
- School children ..... 425
- Sea buckthorn ..... 358
- Seasonal variation 21, 419
- Secondary metabolites  
..... 157, 373
- Seed ..... 37, 436  
pelleting ..... 156  
sizes ..... 188  
systems ... 307, 436,  
529
- Seedball technology . 152,  
156
- Self-help groups 300, 335
- Self-sufficiency ..... 511
- Self-sustaining ..... 28
- Sensitivity analysis ... 53
- Sesame ..... 21, 193, 485
- Shadow prices ..... 535
- Shannon index 73, 91, 114
- Sheep breeds ..... 342
- Shelterbelt ..... 270
- Shrimp production ... 340
- Silage ..... 351, 379
- Silvicultural management  
..... 262
- Silvopastoral systems  
..... 137, 364
- Single nucleotide polymor-  
phism .... 218
- Slow food ..... 443
- Small-scale  
agriculture ..... 523  
dairy ..... 468  
fisheries ..... 328
- Smallholder farmers .. 37,  
61, 67, 90, 110,  
151, 156, 190,  
217, 237, 265,  
271, 279, 280,  
283, 312, 337,  
346, 389, 442,  
445, 462, 493,  
508, 513, 555  
adoption ..... 101  
dairy systems ... 343  
participation .... 455
- Smart packaging .... 388
- Social  
capital ..... 335, 445  
events ..... 299  
learning ..... 308  
networks .. 309, 438,  
507  
expenditure .... 502
- Sociocultural values . 489
- Socioecological  
resilience ..... 51  
systems 36, 50, 253,  
304, 490  
trade-offs ..... 505
- Sociotechnical systems  
..... 198, 298
- Soil  
amendment ..... 174  
carbon ..... 144  
colour ..... 138  
Cu ..... 418  
degradation 250, 254,  
256, 272, 487  
fertility 25, 127, 129,  
136, 138, 158  
health ..... 130  
incubation ..... 141  
macrofauna .... 137  
management .... 274  
moisture ..... 239  
nutrients ..... 138  
organic  
carbon ..... 272  
matter ..... 183  
properties ... 23, 276  
quality indicators ...  
137, 256  
reclamation .... 143  
ridging ..... 243  
sodic ..... 143  
texture ..... 144  
tillage ..... 256  
variability ..... 135  
water ..... 240
- Solanum tuberosum* . 158,  
215
- Solar ..... 235, 386  
drier ..... 390, 396  
energy .... 387, 400
- Solid state fermentation  
..... 378
- Sorghum bicolor* .... 217,  
219, 260
- South Africa 75, 116, 144,  
446, 551
- Southern Africa 314, 330,  
518
- Soybean ... 75, 165, 171,  
214, 243
- Spate irrigation ..... 560

- Spatial  
 analysis ..... 304  
 variability ..... 56
- Spatio-temporal dynamics  
 ..... 229, 259
- Spices ..... 29, 88
- Spider plant .... 134, 192
- SSRS markers ..... 219
- Stable isotopes . 132, 241
- Staphylococcus aureus*  
 ..... 336
- Stinging nettle ..... 420
- Stochastic impact evaluation  
 tion ..... 288
- Stocking rate ... 128, 364
- Stored product moths . 94
- Straw  
<sup>13</sup>C-labelled .... 124  
 management ... 185
- Structural intervention  
 ..... 310
- Sub-Saharan Africa  
 ... 21, 87, 173,  
 286, 524, 548
- Subjective resilience . 492
- Subsistence communities  
 ..... 489
- Suckling .. 334, 336, 370
- Sucrose ..... 34
- Sudan 219, 231, 251, 469,  
 494
- Sugarcane ..... 112, 172  
 bagasse ash ..... 171
- Sulawesi ..... 282–284
- Sunflower . 240, 356, 511
- Supermarkets ..... 428
- Superparasitism ..... 94
- Supplementation 368, 369
- Supply  
 analysis ..... 511  
 chain governance ...  
 112
- Sustainability ... 99, 112,  
 113, 136, 154
- Sustainability ... 189, 343,  
 443, 461, 464,  
 467, 495
- Sustainable  
 agriculture .. 76, 153  
 aquaculture ..... 253  
 development 38, 328  
 intensification ... 50,  
 110, 302, 460,  
 517  
 land management 58,  
 63  
 land-use ..... 187  
 livelihoods 104, 266,  
 284  
 upgrading ..... 458
- Swaziland ..... 514
- Sweet potato ..... 403  
 vines . 351, 368, 369
- Swidden transformation  
 ..... 49
- System  
 efficiency ..... 234  
 comparison ..... 80
- T**
- Tajikistan .. 329, 531, 565
- Tanzania ... 59, 181, 306,  
 315, 402, 405,  
 484, 507, 511
- Tea ..... 55, 93
- Teak ..... 279
- Technical efficiency .. 393
- Technology adoption  
 103, 151, 309,  
 393, 502
- Tensile strength ..... 131
- Termite ..... 81, 429
- Textile industry ..... 286
- Thailand .. 112, 261, 449
- Theory  
 based impact evaluation  
 tion ..... 272  
 of change ..... 113
- Tied-ridges ..... 240
- Timber ..... 279
- Tomato ..... 164, 474
- Trace elements ..... 107
- Tractor ..... 397
- Trade off analysis ..... 65
- Traders ..... 474
- Traditional ..... 377  
 agroforestry ... 182  
 farming systems 394  
 knowledge ..... 430  
 medicine ..... 32  
 value chains ... 455
- Training needs assessment  
 ..... 313
- Trans-boundary  
 cooperation 231, 448  
 water sharing .. 230
- Transdisciplinarity ... 295
- Transformative learning  
 ..... 294
- Trap crop ..... 76
- Tree  
 densities ..... 115  
 domestication .. 281  
 planting ..... 310  
 prioritisation ... 281  
 shelterbelt ..... 277
- Trichogramma* spp. ... 94
- Trophic interactions . 116
- U**
- Uganda ... 114, 138, 139,  
 372, 440
- Ullucus tuberosus* .... 34
- Underutilised plant species  
 313, 410, 534
- Unsaturated fatty acids  
 ..... 356
- Upgrading strategy .. 507
- Urban  
 agriculture 123, 143,  
 192, 314, 339,  
 367, 518, 551

- Urban  
  biodiversity .... 114  
  consumers ..... 474  
UrbanFood<sup>Plus</sup> .. 339, 367  
Urea blocks ..... 369
- V**
- Vaccination ..... 326  
Value chain 372, 457, 459,  
  464, 465, 471–  
  474, 534, 551  
  analysis ... 461, 466  
  development ... 462  
  improvement ... 468  
Variety screening .... 204  
Vegetables 444, 459, 474,  
  513, 554  
  quality ..... 392  
Vegetation  
  ecology ..... 22  
  loss ..... 59  
Vendors ..... 447  
Vermiwash ..... 536  
Vietnam .. 136, 340, 482,  
  492  
*Vigna radiata* ... 185, 241  
Village  
  economy ..... 515  
  general equilibrium .  
  515  
Violin bows ..... 36  
Vitamins .. 357, 418, 425  
Voluntary intake ..... 354  
Vulnerability ..... 195
- W**
- Wage employment ... 480  
WaNulCAS .... 261, 262
- Waste  
  characterisation 108  
  management ... 100  
  value addition .. 108  
Wastewater ..... 123, 545  
  irrigation ..... 143  
Water ..... 503  
  application efficiency  
  562  
  conservation .... 562  
  deficit stress .... 544  
  dispersible clay . 131  
  efficiency ..... 539  
  energy-food nexus ..  
  231  
  institutions ..... 232  
  management ... 233,  
  235, 523  
  manual lifting .. 235  
  pricing ..... 230  
  productivity 270, 564  
  saving ..... 563  
  irrigation .... 227  
  scarcity .... 244, 531  
  sharing        trans-  
  boundary .. 230  
  stress ..... 241  
  sustainability ... 539  
  trade simulation 232  
  use efficiency .. 178,  
  240  
Watershed 255, 259, 479,  
  487  
  management .... 236  
Welfare ..... 251, 439  
  assessment .... 344
- West Africa . 42, 48, 193,  
  217, 262, 332  
Wetlands 22, 23, 139, 194  
Wheat ..... 190  
Wild  
  bee ..... 304  
  food plants 410, 415  
  pollinators ... 27, 28  
  relatives ..... 219  
Wildlife ..... 42, 43  
Willingness to  
  invest ..... 442  
  pay ... 86, 449, 481  
Wind break ..... 270  
Women .... 281, 300, 427  
  empowerment .. 502,  
  513, 517
- Wood  
  ash amendment 156  
  supply ..... 277
- X**
- Xishuangbanna ... 30, 62,  
  125, 255
- Y**
- Yam cultivation ..... 316  
Yayu Biosphere Reserve  
  182, 423, 459,  
  510
- Z**
- Zambia .. 54, 60, 87, 326,  
  552  
*Zea mays* ..... 185, 260  
Zimbabwe 155, 195, 411,  
  496  
Zinc ..... 425



# Abstract IDs

<b>Abstract ID</b>	<b>Page</b>		
10	89	164	545
21	233	178	392
34	29	180	531
36	127	182	179
50	155	183	496
56	378	192	128
59	535	195	26
62	356	199	357
79	280	200	442
80	376	201	443
84	363	202	549
89	154	206	539
90	156	207	385
91	237	208	507
92	389	211	450
94	440	217	342
99	333	219	481
101	564	230	459
113	86	239	299
114	541	247	508
116	196	256	158
119	28	259	300
123	90	263	486
125	27	269	129
128	253	271	393
133	157	274	94
136	390	277	358
138	441	280	460
139	391	281	336
142	53	286	495
143	536	287	394
145	415	289	487
151	416	291	231
155	480	292	54
162	334	293	104
		296	159
		297	301
		302	160
		307	364
		314	55
		315	502
		316	386
		322	255
		323	302
		325	161
		327	436
		329	83
		340	456
		341	303
		342	370
		343	461
		345	462
		346	509
		349	395
		351	105
		353	130
		361	238
		364	99
		365	122
		367	50
		368	444
		370	261
		371	56
		374	352
		379	183
		380	445
		381	417
		382	230
		383	57
		386	437
		387	304
		388	540

389	377	471	465	603	248
391	493	476	306	604	266
392	305	478	58	606	93
393	131	480	512	607	164
394	544	484	458	609	400
397	270	485	418	611	492
398	287	487	384	612	290
399	455	493	251	615	32
401	298	497	438	617	38
402	206	501	396	618	73
404	529	502	234	622	537
405	162	503	551	628	37
406	232	505	25	630	107
408	457	508	59	633	296
409	463	511	135	634	401
410	184	516	106	639	402
413	188	527	485	640	165
416	229	533	163	641	214
417	152	535	412	645	419
425	51	536	360	647	138
426	387	540	329	648	139
427	351	541	60	649	563
429	374	542	217	650	150
430	20	546	213	652	309
431	198	549	34	654	482
432	294	554	181	655	310
433	375	555	218	656	272
436	359	559	307	657	124
437	95	562	33	658	153
438	132	572	513	659	534
441	353	576	308	661	361
442	133	581	136	663	91
443	35	582	340	664	344
444	488	583	126	668	514
445	297	585	189	669	515
446	464	586	372	671	108
448	479	590	538	672	274
450	411	593	397	673	260
453	74	594	398	678	194
457	49	596	259	679	435
460	510	597	484	680	197
467	511	598	399	681	166
468	134	600	137	682	219
470	503	601	466	685	365

---

687	110	791	341	873	388
690	88	792	208	880	337
698	111	795	422	881	250
700	311	797	209	882	72
701	265	798	235	884	518
704	371	799	21	888	562
708	420	800	113	889	448
710	112	801	491	891	30
714	338	802	203	892	170
715	413	808	366	893	404
717	403	809	447	895	63
719	467	813	345	897	430
721	497	814	240	900	483
722	192	817	312	901	543
724	257	818	354	902	519
725	256	820	82	905	449
728	326	821	504	906	335
729	439	823	190	907	505
730	516	824	61	908	258
732	327	827	78	909	471
733	429	828	414	910	41
738	23	830	168	911	472
742	211	831	193	912	295
747	215	832	446	913	39
751	182	833	204	914	346
752	254	835	85	915	180
753	22	837	220	918	520
754	87	841	313	922	423
755	140	844	43	923	532
758	286	846	92	930	273
759	151	847	169	931	79
760	239	850	141	933	405
762	167	851	36	937	207
765	325	852	262	938	242
766	421	854	379	939	424
767	468	855	212	940	425
768	185	856	470	941	426
769	410	858	187	944	542
771	178	860	42	945	100
775	210	862	186	948	252
781	373	863	517	950	31
784	84	866	314	951	473
789	227	868	62	954	80
790	76	872	241	955	315



956 .....	48	1009 .....	355	1079 .....	330
960 .....	285	1019 .....	339	1080 .....	362
962 .....	171	1025 .....	331	1081 .....	524
964 .....	427	1027 .....	522	1082 .....	506
966 .....	102	1030 .....	221	1084 .....	75
967 .....	228	1031 .....	428	1086 .....	332
970 .....	101	1033 .....	318	1089 .....	279
971 .....	52	1035 .....	66	1090 .....	281
976 .....	264	1036 .....	530	1091 .....	282
977 .....	243	1039 .....	454	1092 .....	283
978 .....	275	1041 .....	523	1093 .....	284
979 .....	494	1042 .....	67	1094 .....	288
980 .....	343	1044 .....	216	1095 .....	289
981 .....	64	1045 .....	489	1096 .....	278
985 .....	474	1048 .....	271	1097 .....	276
988 .....	191	1049 .....	173	1098 .....	277
989 .....	103	1059 .....	116	1099 .....	552
991 .....	65	1060 .....	123	1100 .....	554
993 .....	367	1061 .....	174	1101 .....	555
994 .....	114	1062 .....	368	1102 .....	12
996 .....	324	1064 .....	369	1103 .....	558
997 .....	406	1065 .....	142	1104 .....	559
1000 .....	172	1066 .....	328	1105 .....	560
1001 .....	115	1068 .....	195	1107 .....	202
1003 .....	490	1070 .....	244	1108 .....	548
1004 .....	125	1072 .....	143	1109 .....	14
1005 .....	521	1073 .....	144	1110 .....	478
1006 .....	81	1075 .....	145	1111 .....	13
1008 .....	316	1076 .....	236	1112 .....	565