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Swedish University of Agricultural Sciences

SLU Global

The SLU Global Food Security Research and Education Program 2010-2013

A Swedish Government Initiative

SLU-Global Report 2013:2

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SLU Global

Final report

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Agricultural Sciences for Global Development (SLU Global)

Swedish University of Agricultural Sciences

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Enhanced African food production – key for Africa and the world

Lennart Båge
Ambassador
Vice Chair of the Executive Board of the Swedish University of Agricultural Sciences and former President of IFAD (the International Fund for Agricultural Development)

Why is there so little concern expressed over global food security in the development debate in Sweden? Food on the table is the key poverty issue facing over a billion poor people – still today. And growing food is what most people in the poorest countries do for a living. When food production is enhanced and delivers a greater harvest that is when development starts. If this is sustained over time a virtuous circle is created. It spurs development, economic growth, health and nutrition, poverty reduction and the energy and resources for transformation of livelihoods. This is exactly the process - with all its national specificities and peculiarities – that has been repeated in country after country since the 19th century. Since the Second World War, increases in agricultural productivity have fueled economic growth in South Korea, Taiwan, Thailand, China and more recently and spectacularly in Vietnam – just to mention a few Asian "miracle" countries. When poverty was made a key issue for political attention in the 1960's the world took a number of measures captured in the concept of the green revolution. It delivered – famines and hunger became more and more rare, particularly in Asia.

Africa however, for a number of reasons, was left behind. It lacked institutions for underpinning an African green revolution. It was flooded with cheap subsidised and dumped surplus food from other continents. It lacked the resources to invest in a more productive smallholder economy. The improved seed, the extension service, the feeder roads, the credit, the irrigation, the storage facilities, the traders and many other parts of the complex institutional infrastructure that is needed for development of the agricultural sector was lacking or was weak. Add to that the waning interest from national politicians dependent on vocal urban constituencies, and the equally waning interest from the development partners and consequently interest in and understanding of the rural development challenge disappeared from the mainstream development agenda.

The food price crisis in 2007/8 changed this. All of a sudden food prices more than doubled. Food markets were closed, export bans were put in place, droughts and floods wreaked havoc in the production systems and food security became a key issue even for G8 and G20 summits.

While the acute crisis has subsided, the food price index is still twice as high as it was in 2007. Food reserves are at three months consumption, prices are volatile and hard to forecast due to more unpredictable weather conditions in key production areas, not least due to climate change and – in many parts of the world – growing water scarcity.

Against this backdrop we look at Africa. Africa is the only continent where food production has not been boosted over the last decades. Africa is the continent where population growth is the strongest and it will more than double its population by 2050 adding more than a billion human beings. This is a development challenge of huge proportions.

Africa is characterised by a number of paradoxes. It is rapidly urbanising yet still predominantly rural. Its economic growth is record high yet hardly a dent is seen in the poverty panorama in many countries. Despite rapid economic growth, about 70% of the population is dependent on agriculture and related services for their livelihoods. Africa's big blessing to date – and in many cases also its curse – has been raw materials used mainly for export. Industry and services will undoubtedly grow but no one expects these sectors to provide all the jobs rapidly needed for the burgeoning young populations.

Agriculture could and should be the backbone of economic growth, job creation and poverty reduction – as it has been in virtually all other countries at this stage of their development. Africa should be able to prosper not only from what it extracts from the ground but also from what it sustainably grows on the ground. And while single-source mineral and oil assets can easily be captured by a small segment of the population, smallholder agriculture of the kind that flourishes in Asia delivers incomes and livelihoods to millions of farmers, their families and communities.

Not only Africa needs to be fed but also the

world. Over the next 40-50 years 60-100% more food needs to be produced to meet the demands from a growing world population which will reach 9 - 10 billion by 2050. According to all forecasts it will be a more affluent world population that not only will demand more food but also a much more varied diet. People increasingly are graduating from the staples they rely on when poor, to the vegetables, dairy products and meats that accompany development and growing prosperity. The production challenge this represents is amplified by the growing effects of climate change and water scarcity. Africa has in its agricultural potential not only a great asset for its own development – emulating what we have seen in earlier decades in Asia - but also an asset for meeting a growing global demand for food, feed, fiber and fuel.

It is thus paramount to engage with African agriculture – for the sake of African development but also for the sake of the world. To develop its agriculture Africa needs political commitment, which is now gradually growing as more and more countries (though still only 7 out of 53 countries) meet the Maputo declaration of allocating 10% of national budgets for agriculture. It needs investment resources and not least an institutional infrastructure of education, research, extension and advisory capabilities as well as resources for providing credit, feeder roads, storage, a trading system and all the other components of a thriving food and agriculture industry – building on a vibrant smallholder farming community.

One key component is higher education and research at the national level with links to the regional and international levels. To develop higher training and research capabilities has long been on the agenda but is significantly underfunded. To train and develop the manpower needed to service an expanding and flourishing food and agricultural sector is of crucial importance. Africa still spends much less of its resources – public and private – for higher education and research than the rest of the world.

The Food Security Initiative that the Swedish Ministry of Foreign Affairs has financed and that in part has been implemented by the Swedish University of Agricultural Sciences (SLU) and partners, is a clear example of what is needed and what can be done to strengthen African capabilities through institutional cooperation and collaboration. This is of obvious importance to African development but also for building the bilateral and multilateral research and training networks needed for addressing the growing global challenges. The future food and climate challenges will not be met in national isolation but only through global and regional collaboration. Strengthening African institutions to play their part in this is of utmost importance – both to African food security and to global food sustainability.

Most of the food needed in the future has to come from increased productivity on existing farmland through sustainable intensification. There is limited scope for large-scale area expansion – globally as well as in Africa. High food prices give incentives for increased production and bring up the value of land. Add to this the growing interest in bioenergy and it is easy to understand why there has been such a scramble for land in Africa especially since 2007/8. The ability of African governments to manage this huge increase in demand – both by international companies and foreign governments as well as by domestic actors – has in many cases been weak. It requires a legal framework, knowledge about social conditions, customary rights, land-use practice and potential, the nature of agro-ecological zones, institutional frameworks and many other aspects around the issue of land utilisation.

These are just a few of the crucial issues that require an African capacity for higher training, research and development. Others concern yield increases – more crop per drop – and all other aspects of increased productivity. Just to go from one ton per hectare to two, low by Asian standards, is a daunting challenge of research, extension and outreach. Other crucial issues concern the role of women (the African farmer is more often than not a woman), the challenge of storage to bring down the, on average, 30% harvest loss, the challenge of climate change and of water scarcity. The ultimate challenge is to promote agricultural practices that deliver food security and development and that are sustainable – ecologically, economically and socially – over the longer term. All this clearly requires a concerted African and international effort where Sweden should play its role of providing support and collaboration.

Introduction

Arvid Uggla
Professor
Director SLU Global

The Swedish University of Agricultural Sciences, SLU, is unique in Sweden. Our university is devoted to agricultural and environmental sciences in their broadest sense, including forestry, veterinary and animal sciences as well as landscape architecture and has the specific governmental mission to conduct national environmental monitoring and assessment. According to international rankings SLU is one of the world's leading universities in the field of agricultural sciences. We have a long tradition of participating in development cooperation and capacity-developing activities together with partner universities and research institutes in different parts of the world. SLU's programme Agricultural Sciences for Global Development (SLU Global) creates a platform for international development cooperation in research and higher education, and is responsible for the consolidation and communication of the projects presented in this report.

Since highlighted in the World Development Report of 2008, there is a growing consensus that agricultural development is the basis for economic growth in low-income countries. Furthermore, agricultural development is also the best way to achieve growth that reaches the rural poor and most vulnerable; in sub-Saharan Africa for example, it is estimated that 70% of the workforce is engaged in the agricultural sector. It is also well established that failure to ensure food security threatens political stability and social welfare. Thus the development of a sustainable and resilient agricultural production based on knowledge and innovation should be regarded as a political necessity in most countries. This is indeed acknowledged by the African countries themselves who, with their joint declaration in Maputo in 2003, created the Comprehensive Africa Agriculture Development Programme (CAADP) which sets a target of an annual 6% growth in agricultural GDP. The Swedish government clearly recognises the fact that global food security and agricultural development are key areas worthy of long-term support. This was made apparent following the recent international food crisis, when the government allocated specific funds from its development budget to support durable food security initiatives aiming at reducing hunger and malnutrition, particularly in sub-Saharan Africa. The aim was to establish research and education partnerships that could then address future needs within food security in a long to medium term perspective.

In October 2010 the Ministry of Foreign Affairs decided to contribute 40 million SEK, equivalent to approx. 6 million USD, to SLU from this special allocation supporting global food security. SLU's mission was to engage with institutions in low-income countries, conduct high quality collaborative research and education and implement the results. Research collaborations were also meant to enhance and develop the capacity of partner institutions. Priority areas included plant breeding, farming systems, animal health and disease control, and the program was to be run over two years, 2011 and 2012. Due to unforeseen external circumstances some of the projects could not be carried out as originally planned. SLU was therefore granted a no-cost 6-month extension on use of funds to accomodate implementation of these revised projects.

In this report we present the work achieved, and summarise the results from a total of 24 subprojects grouped into 11 main topics. The projects were conducted in Africa, with the exception of three that were carried out in Central and Southeast Asia. They all deal with research aspects regarding how to supply a growing global population with safe and nourishing daily food, while also considering the need for environmental, social and economic sustainability in agricultural production, including manure management. Several of the projects have added to, and augmented, on-going or recently finalised projects mainly supported by Sida[1].

In this reports volume, the subprojects are grouped under their respective main topic, each of which has a common introductory synthesis (a few solitary projects excepted). Aggregated quantative data such as number of publications produced, number of students involved and other outputs from the projects are presented in appendices at the end of the volume. Both the capacity

development and the pure scientific aspects of the program have met the highly-set standards of the program.

As a result of this program:

- 29 universities and 34 research institutes and organisations in 23 countries were involved in the collaborative activities
- 60 MSc and BSc students were able to produce their thesis work and receive their degrees (many accessible from the Epsilon archive http://stud.epsilon.slu.se)
- 27 PhD and Licenciate students received support for their research activities
- 21 scientific conferences/workshops were organised
- 28 courses and other training activities for students or academic staff were conducted
- 27 workshops or courses were organised for farmers or other end-users
- 17 scientific papers were published in peer-reviewed international journals
- 61 manuscripts with results from the involved studies are in preparation for submission to scientific journals
- In addition, a substantial number of popular science articles, book chapters, pamphlets and teaching materials have been produced.

If we consider the impact of the program in a wider perspective, it has contributed to capacity development not only at the participating universities and other academic institutions, but also for the society as a whole. Many of the involved students have a great interest in global development issues and are looking for careers outside academia both in their home countries and internationally. This program provided invaluable opportunities for them to deepen their knowledge by conducting studies and research. It was especially beneficial for students at African universities where mechanisms such as the Minor Field Study grant do not exist.

As mentioned, during the course of the program each participating project has run their own workshops and conferences in collaboration with their respective partner institutions. To further enhance the alliances with African and Asian partners, the program organized a joint conference located in Kampala, Uganda in December 2012. Another opportunity for partnership interactions was during the concluding program symposium held at SLU, Uppsala, in June 2013. These enabled both the SLU researchers and their partners to discuss the results achieved and, not least important, to plan for follow-up collaborative initiatives and interdisciplinary partnerships. The importance of the Kampala symposium was highlighted by the attendance of the Swedish ambassador to Uganda and of representatives from AGRA[2], RUFORUM[3], TEAM-Africa[4], Sida, Makerere University and other universities from the East African region and from Central Asia. The concluding symposium at SLU was attended by the State Secretaries of both the Swedish Ministry for Foreign Affairs and the Swedish Ministry for Rural Affairs as well as by key note speakers from ANAFE[5] and AGRA. The proceedings from the Kampala symposium and other information concerning this program can be found on SLU Global's webpage www.slu.se/slu-global.

For review and compilation of this report special recognition is due to SLU Global staff Drs Helena Eklund Snäll, Niklas Nordquist and Philip Chiverton, and to Malin Planting for editing and graphic design.

On behalf of SLU and our partners in Africa and elsewhere we wish to express our thanks to the Swedish Ministry for Foreign Affairs for its foresight and generous support of this program. This support has contributed strongly to consolidate an extensive network – both professionally and geographically – that includes key universities as well as national and international institutes and organisations. This means that a valuable platform is now established for continued investments in collaborative agricultural research and capacity development activities between SLU and its partners in low-income countries. The platform is an integral component in the maintenance of a Swedish, internationally competitive resource base in the fields of agricultural and environmental sciences, and has the commitment and capacity to participate in future efforts to contribute to a sustainable global food security.

[1]Swedish International Development Cooperation Agency

[2]Alliance for a Green Revolution in Africa

[3]Regional Universities Forum for Capacity Building in Agriculture

[4]Tertiary Education for Agriculture Mechanism in Africa

[5]African Network for Agriculture, Agroforestry and Natural Resources Education

Photo: Jan Willem de Besten

Photo: Christina Johansson

Photo: Stephen Shivachi

Photo: Jennie Stein

1. Improved local varieties: Plant genetics and Biotechnology – East Africa

Lena Granehäll (MSc student, SLU) and Violet Akech (Makerere University) preparing plants at Kabanyolo station, outside Kampala, Uganda.

Photo: Moses Biruma

Photo: Beatrice Ang'iyo

Variety trials on sorghum outside Nairobi, Kenya.

Synthesis

Plant breeding activities generate seeds for multiple uses e.g. food and feed products, bioenergy, and raw materials replacing mineral oils; all these play a crucial role for human health and welfare. In most cultivated crop species there is limited genetic variation available for the development of new, high yielding varieties adapted to climate change and sustainable farming practices. In general, wild progenitors as a group contain more genetic diversity than domesticated varieties. The domestication processes have caused genetic bottlenecks and loss of genetic diversity. This process has resulted in a more or less narrow genetic base available for crop improvements today. Distant relatives of crop species provide a vast and largely untapped reservoir of genetic variation for a wide range of agronomical important traits that can be exploited by breeders. However, wide species crosses result in introduction of a less desirable genetic load and the materials require a combination of back-crossings and excellent selection systems to achieve successful integration in elite germplasm.

Future challenges for mankind are numerous and possess high levels of complexity. Prognosis on effects deriving from climate change, population growth and growing urbanisation imply constraints that together put an enormous burden on our agricultural systems and food production. In reality many predicted "future" constraints already exist. For example, we are in this very moment experiencing unpredicted rain seasons resulting in huge crop losses in sub-Saharan African due to drought, whereas regions in India and Canada have experienced catastrophic flooding. Responsibilities on securing seed production in a worldwide perspective are far from clear and urgently require solutions to avoid significant national or private monopoly dependencies, and/or inadvertence and negligence leading to worldwide food crises. Adapting materials to today's problems with for example drought stress should have started already 20 to 30 years ago. Time constraints mean that speeding up the breeding processes is crucial. Rice, wheat and maize are the three dominating staple crops in the world. They provide the basis of daily calorie intake for billions of people. Consequently, a complete yield loss of any of the "big three" would be disastrous and must be avoided. This heavy dependency also calls for an expansion of more crop species to be grown but most of those plant species require much breeding input to be productive.

Plant breeding has a long history of integrating the latest innovations in biology and genetics to improve crops. The scientific basis for plant breeding and genetics at the turn of the 20th century derive from the discoveries of Darwin and Mendel. Crop advancements of the 21st century are based on advances in genomic research, and molecular marker applications, integrated with conventional plant breeding practices. This new knowledge and tools have huge potential not least if and when implemented in low-income countries. To succeed, education and research is required to exploit these new possibilities.

The two breeding projects in this program, on sorghum and yellow nutsedge, reported below, contribute with expanded gene pools in various breeding materials. Furthermore, they introduce important traits from related species and this is the first step of exploitation of crop genomics and generation of molecular markers to make the selection procedures of desired genotypes more precise.

Christina Dixelius (coordinator)

Disease breeding in sorghum – MAS technology and dissemination of information

Project leader: Christina Dixelius

Summary in Swedish

Förädling för sjukdomsresistens i sorghum; MAS-teknik och kunskapsspridning

Sorghum är en viktig inhemsk stråsädesgröda i Afrika. Den försörjer fler än hälften av Afrikas småbönder på landsbygden. Avkastningen är dock mycket låg jämfört med länder utanför Afrika. Förutsättningarna för ökad skörd är goda men förutsätter riktade förädlingsinsatser. Förutom högre avkastning krävs anpassning till det allt mer förändrade klimatet, till exempel egenskaper som ger torkhärdighet, tolerans mot skadeinsekter och svampsjukdomar, eller kvaliteter som möter nya behov från en begynnande livsmedels- eller foderindustri. Syftet med projektet var att både identifiera och introducera viktiga egenskaper i förädlingsmaterialet samt att effektivisera själva förädlingsarbetet med hjälp av molekylära verktyg.

För detta syfte har tre vilda arter av sorghum (*S. propinquum, S. arundinaceum S. verticilliflorum)* använts i korsningar med utvalda lokala varianter. Avkomma från dessa korsningar ingår i nya förädlingsprogram och utgör även stommen för att kunna koppla samman egenskaper med molekylärt baserade markörer. Vidare har arvsmassan hos de tre vilda sorghum-arterna kartlagts med DNA sekvensering. Denna kartläggning har möjliggjort identifiering av ett stort antal nya DNA markörer som i förlängningen kan användas för att koppla samman markörer med eftersträvansvärda egenskaper som påverkar avkastning, torkhärdighet och sjukdomsresistens. Inom växtförädling blir användandet av molekylärt baserade verktyg i kombination med kunskap om hur olika grödors arvsmassa är uppbyggd helt nödvändigt för att möta morgondagens krav på en ökad och säker livsmedelsproduktion.

Summary

Sorghum is an important domestic cereal crop in Africa that provides food and income for more than 50% of the rural households. However, the current production level of sorghum is low compared to countries outside of Africa. The prospects of improved yields and new food/feed products are high but require substantial improvements through plant breeding. Sorghum suffers from many fungal diseases and insect pests, and other constraints common in the region such as acid soils that hamper root development and nutrient uptake. The aims of this project were to identify and introduce important traits in plant breeding material, and to facilitate plant breeding through the use of molecular tools.

Three wild varieties of sorghum (*S. propinquum, S. arundinaceum S. verticilliflorum*) were used in crosses with selected local sorghum materials. The offspring from these crosses are being used in new breeding programs, and also constitute a platform for linking desired traits to molecular markers. Furthermore, the genomes of the wild varieties of sorghum were characterised by DNA sequencing. This characterisation has enabled the identification of a large number of novel DNA markers, which are essential for linking markers to desirable traits such as yield, drought hardiness and resistance against disease. In plant breeding, the use of molecular tools in combination with knowledge of plant genome structure and function will be pivotal for addressing future needs of an increased food production and food security.

Background

Maize (*Zea mays*) and sorghum (*Sorghum bicolor*) are the most important staple cereals for sub-Saharan Africa. While maize is an introduced crop and grown in Africa for ~150 years, sorghum domestication probably dates back to the advent of agriculture in sub-Saharan Africa ~10,000 years ago. Today, it is an established understanding that the sub-Saharan and North East regions of Africa are the primary centers of sorghum diversity. The sorghum crop is generally cultivated in marginal regions of the continent and is a key component of more than 50% of Africa's rural household livelihood strategies. In spite of its pivotal role in the region's agricultural development agenda (fairly drought hardy crop that suits climate change resilience), the current production level of sorghum

Sorghum.

Photo: Samuel Gudu

is low, less than one ton per hectare. This is because sorghum cultivation is still characterised by traditional farming practices, with low inputs and use of unimproved landraces. Maize is not a particularly drought hardy crop and yield losses are starting to occur. Thus, emphasis on improvements of crop species more adapted to regional environmental constraints is of extreme importance to secure food production. In a former collaboration within the BioEarn program, new sorghum germplasm was collected and evaluated for agronomic performances. It became clear that the existing breeding materials needed further genetic expansion. In present work we selected three well-adapted and resilient sorghum species and crossed them with advanced local sorghum materials. *S. arundinaceum* and *S. verticilliflorum* harbor traits such as high resistance to sorghum midge, and shoot fly as well as very high tolerance to several fungal diseases, and drought. *S. propinquum* has higher nutritional value due to altered storage protein content. We also wanted to exploit molecular information to develop markers to speed up selection in subsequent breeding generations. To this end we initiated a genomic selection program since the sorghum genome is known and can constitute a model for new breeding initiatives of many more crop species.

Collaborators

SLU

Christina Dixelius (project leader), Johan Fogelqvist, Tom Martin – Dept. of Plant Biology and Forest Genetics, Uppsala, Sweden

NaSARRI - the National Semi Arid Resources Research Institute, Entebbe, Uganda
Moses Biruma (PhD student)

Makerere University, Kampala, Uganda
Patrik Okori, Emmanuel Okalany (BSc student), Charles Liri (MSc student) – Dept. of Agricultural Production

Approach

Three well-adapted and resilient sorghum species *S. arundinaceum, S. verticilliflorum and S. propinquum* were selected and crossed with advanced local sorghum materials (mainly done by Moses Biruma at NaSARRI, Uganda). Seeds from the crosses were planted, and flowers selfed. The wild species-hybrid crossings were repeated to enlarge the size of the F1 plant populations. This new plant material will be introduced into ongoing breeding programs but also used to generate association-mapping populations to link up with the molecular work.

Total DNA from the three wild species were prepared, and used for pair-end library construction. Libraries (200bp and 800bp) from each species were generated and sequenced using Illumina technology. The raw data was mapped to the sorghum reference genome, followed by further bioinformatics analysis of SNP and INDEL distributions.

Scientific results

DNA from the three species was sequenced and compared with the sorghum reference genome. *S. propinquum*, which is more distantly related to *S. bicolor,* thus showed the highest number of single nucleotide polymorphisms (5,985,855 homozygous; 1,472,228 heterozygous) compared to *S. verticilliflorum* (2,343,087 homozygous; 641,923 heterozygous), and *S. arundinaceum* (2,580,120 homozygous; 992,486 heterozygous). INDEL data from the three species varied in accordance. Current results together with previous work within the Sida-funded BioEarn program form the basis for more efficient breeding and thereby faster production of new improved sorghum varieties.

Facts about sorghum

Sorghum

- is an important staple crop for millions of people in the semi-arid tropics of Asia and Africa.
- is a cereal related to maize and sugarcane, which can grow in harsh environments with limited water resources.
- Sorghum is divide into five so-called races: kafir, guinea, caudatum, bicolor and durra. Local names flourish: great millet or guinea corn (West Africa), kafir (South Africa), dura (Sudan), mtama (Eastern Africa), jowar (India), milo-maize (USA).
- The dehulled grains of sorghum can be boiled and used like rice, or milled to flour and used in various types of food preparations.

Dissemination of results

Visits

Charles Liri, an MSc student from Makerere University was visiting SLU in May 2011 to learn plant transformation techniques.

The SLU team visited Makerere University in October 2011 to discuss new courses in collaboration with RUFORUM. Further details were discussed during the recent visit at Makerere University in December 2012.

A visit by Moses Biruma to the Dixelius SLU team is planned for September 2013.

Capacity building

Moses Biruma: Development of molecular based tools for resistance breeding of sorghum to *Colletotrichum sublineolum*. PhD thesis submitted spring 2012 to the Graduate Office, Makerere university, defended August 2013. Final work on thesis writing was supported by this project.

Charles Liri: Development of sorghum germplasm resistant to striga, drought and turcicum leaf blight. MSc thesis, to be defended 2013. Part of the work was done within the project.

Emmanuel Okalany: Agronomic performance of advanced (pre-released) sorghum lines. BSc thesis 2012. Part of the work was done within the project.

Workshops and courses

Sorghum workshop 13-18 October 2011, Entebbe, Uganda, organized by P. Okori & C. Dixelius.

Teaching in the PhD course "Plant breeding & crop production – meeting the 2050 food security demands" 4.5 HEC, 16-20 May, 2011. NRML/SLU research school. P. Okori & C. Dixelius were among the teaching team. 12 of the 22 students came from low-income countries.

In the PhD course "Agrigenomics" 4 HEC, Organism Biology research school, SLU 14 Dec. 2012-27 Feb. 2013, Wubishet Bekele, an Ethiopian PhD student studying at Justus Liebig University Germany was invited to teach on the subject "Genomic selection on sorghum".

Outreach materials

The production of an E-book with free access was discussed at the sorghum workshop, held in Entebbe 2011.

Innovations

Associate Professor P. Okori and his team are presently developing sorghum products for various new applications, e.g. as fish and poultry feed. Most of that work is taking place within the BioInnovate program (The Bio-resources Innovations Network for Eastern Africa Development Program).

Gender aspects

Female students and teachers have participated in all our workshops and capacity developing activities. The project leader Christina Dixelius plays an important role as mentor of young female students.

Females constitute a large proportion of the end user category among small farmers. It is important to demonstrate and discuss new plant materials and their different use with this group. Such activities are taking place at the NaSARRI breeding station and at Makerere University Agricultural Research institute, Kabanyolo (MUARIK). Boarding possibilities for women and children are arranged at these stations to facilitate their participation.

We intend to review and update information on the role of females in todays and tomorrows food production in East Africa. One chapter is devoted to that topic in the drafted E-book.

Photo: Samuel Gudu

Sexual crossings in sorghum breeding. Bags protect the flowers from external cues like undesired pollen contaminations, insects and birds.

"We have extended the gene pool of sorghum and thereby contributed to secure future needs and potentially food security"

Photo: Samuel Gudu

Field day in Kenya.

Greatest value of the program

We have:

- extended the gene pool of sorghum and thereby contributed to secure future needs and potentially food security.
- developed new molecular markers.
- generated new genomic information on three wild species.
- initiated work on new breeding methodologies.
- contributed to capacity development, and an understanding of the power of genomics.
- contributed to north-south collaboration and an understanding of each other's cultures.
- established new and extended collaborations with additional groups working on sorghum.

The way forward

Plant breeding is a long-term assignment, and therefore requires long-term commitments from funding agencies to generate success stories. Interestingly, breeding is currently facing a paradigm shift. The completion of genome sequences for many important crop species and plant pathogens together with the rapid development of computer technologies provide several new strategies to accelerate production of new plant varieties. These advancements give many more options and better precision in the work of finding superior plant genotypes. If optimal, times between cycles of crossings could be up to 15 times faster using genomic selection approaches. To feed nine billion people 2050 requires investments in new food and farming practices. From a plant breeding perspective, we must have resources to act now in order to have seeds of improved crops tomorrow.

A summary of the statistics for this project on p.151

Genetic resources of yellow nutsedge *(Cyperus esculentus* L.*)* in Kenya and parts of East Africa

Project leader: Anders Carlsson

Summary in Swedish

Genetiska resurser hos gul jordmandel (*Cyperus esculentus L.)* i Kenya och delar av Östafrika

Delar av Östafrika lider av en osäker livsmedelsförsörjning orsakad av bl.a. biotisk och abiotisk stress på existerande grödor, men också av ett smalt utbud av basgrödor. Vid sidan av att arbeta med att öka stresstoleransen hos grödorna finns därför ett behov av och en potential i att diversifiera livsmedelsförsörjningen genom att inkludera icke-konventionella grödor.

Detta projekt har undersökt en ny potentiell gröda för Östafrika, gul jordmandel, genom analys av genetisk diversitet, avkastning och näringsinnehåll hos jordmandel från olika platser i Östafrika.

Resultaten från arbetet med jordmandel visar att vilda varianter av jordmandel i Östafrika har liknande kapacitet som odlade sorter från Europa med avseende på avkastning och näringsinnehåll i knölar. Analys av den genetiska diversiteten visade att odlade och vilda varianter av jordmandel klart skiljer sig åt. De vilda varianterna uppvisade också en stor genetisk diversitet vilket visar på en potential i att identifiera varianter som är lämpliga att förädla till nya odlingssorter.

Vår slutsats från arbetet med jordmandel är att det finns en klar potential för att utveckla gul jordmandel till en produktiv gröda i Östafrika vilket bidrar till att erbjuda hushåll på landsbygden både en tryggad livsmedelsförsörjning och ett sätt att förbättra sina inkomster. Dock behövs mer forskning och utvecklingsarbete som bör inriktas på att identifiera fler lovande varianter av jordmandel i Östafrika och omgivande regioner. Vidare bör lokala jordbrukare engageras för att optimera odlingen av jordmandel. Att utveckla värdekedjan som knyter samman odlare av jordmandel med lokala marknader och rättvis handel riktad mot "nisch"-konsumenter i Europa är också viktigt. Inledande kontakter med potentiella europeiska köpare av ekologiskt odlade jordmandelknölar har varit mycket positiva.

Summary

Parts of East Africa suffer from food vulnerability which is caused by, amongst others, biotic and abiotic stresses on existing crops, and a narrow range of staple crops. Therefore, in parallel with the work on increasing the stress tolerance of crops there is a need to diversify food sources by adopting non-conventional crops.

This project has assessed a potential new crop for East Africa, yellow nutsedge, by determining the amount of genetic diversity, yield, and tuber nutrient composition of nutsedge varieties collected from different localities in East Africa.

The regional populations of nutsedge contain variants with similar properties as cultivars from Europe with respect to yield and tuber nutrient composition. Assessing the genetic diversity revealed clear differences between cultivars and wild accessions, and broad diversity within and among accessions of the latter. This broad diversity will be useful for the selection of new breeding varieties for domestication.

Our conclusion from working with nutsedge is that there is a clear potential for the development of yellow nutsedge as a productive crop in East Africa thereby helping to provide rural households with both food security and a way to improve their incomes. However, more research and development work are needed, and this should be focused on identifying additional promising varieties of nutsedge from the area and surrounding regions. Furthermore, local farmers should be engaged to investigate practices that optimise nutsedge cultivation. Attention is also needed to develop a value participatory chain that links nutsedge growers to local markets and fair trade targeting "niche" consumers in Europe. Initial contacts with potential European buyers of organically-grown nutsedge tubers have been very positive.

Background

To alleviate the problems of malnutrition, the use of nutritious foods from local sources has been greatly advocated. Tubers are among

Tubers of yellow nutsedge (*Cyperus esculentus* L.)

Photo: Anders Carlsson

the most common staples used for this purpose in Africa. Yellow nutsedge (*Cyperus esculentus* L.) may be known as a most troublesome weed, nevertheless it is valued because of its nutritious tubers that are used as food in some countries in West Africa and in Spain. A measure of the commercial potential of cultivating yellow nutsedge is that about 2000 tonnes of tubers are exported annually from West Africa to Spain. However, in spite of its great potential as a nutritious crop, it is not exploited in large parts of Africa including East Africa. The use of local varieties and genetic resources of yellow nutsedge for food could improve food security and reduce poverty among rural communities in East Africa. A safe production of high quality and yield of tubers from nutsedge will increase options for local farmers to produce enough food to be able to sell at the local market or for export. The aim of this project was to provide knowledge on the diversity (genetic and tuber nutrient composition) of yellow nutsedge in East Africa; to gather information on genetic relatedness between the European and African types of yellow nutsedge and, above all, to show the economic potential of this crop, especially in Kenya and other African countries where this plant is currently considered as a weed.

Collaborators

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Approach

Yellow nutsedge (*C. esculentus* L.) accessions were collected from Kenya, Uganda and Tanzania, and reference accessions and cultivars from Spain and some parts of the Nile valley in Egypt. All collected wild accessions were multiplied in containers in Kenya for four months. Accessions that showed good establishment were included in field trials together with cultivated/reference varieties. Harvesting was done after four months and the tuber weight, number, and total biomass was determined. Cultivation of all the plant material was subsequently carried out in a controlled environment in Sweden and tubers harvested. Proximate analysis was done using standard procedures to determine oil content and quality, carbohydrate and protein composition of the tubers.

Genetic diversity was assessed using morphological and molecular (Simple Sequence repeat, SSR) markers. SSR markers were developed from sequenced transcriptomes of developing tubers and other tissues of yellow nutsedge. Cluster analysis was done using tuber yield, days to flowering, leaf morphology scores, and marker analysis. Cultivated varieties were included for comparison. A total of 89 EST-SSR primer pairs were developed and tested. Twenty SSR markers were used to assess genetic diversity among the wild and cultivated yellow nutsedge.

The sensory attributes of four types of products were studied. The four types of products - cakes, bread, cookies and porridge - were developed using recipes that included flour from yellow nutsedge. Sensory analysis using descriptive panels for each type of product was carried out.

Scientific results

Fiftysix diverse wild accessions from Kenya, Uganda and Tanzania, and five cultivars/reference accessions from Spain and Egypt were included. Most of the accessions were found in recently cultivated farmlands in wet and dry ecosystems. The accessions were more commonly found in the medium to high altitudes areas. Out of the 56 accessions grown in pots, ten had good growth habits and tuber yield. Six of the promising wild accessions and four cultivated yellow nutsedge varieties were evaluated in the field. The highest tuber yield was recorded in two cultivars and one wild accession. These three also had the highest biomass yield. It appears that the wild accession (from Tanzania), has potential to be developed as a cultivar for tuber production.

Using plant materials raised from tubers grown in pots, it was found that the accessions were very diverse in growth habits including tuber yield,

tuber numbers and total biomass. The accessions also exhibited significant diversity on the basis of leaf morphology, plant height, floral parts and days to flowering. These morphological and physiological differences suggest a rich underlying genetic variation among the accessions.

Genetic differences among the yellow nutsedge populations were also evaluated using SSR molecular markers, developed within the project. Clustering analysis was used to group the accessions. The material separated into two distinct clusters, namely cultivated and wild yellow nutsedge. Overall, the SSR analysis revealed wide diversity within and among accessions of the latter cluster. Lipids, protein and carbohydrates are the major constituents of nutsedge tubers. Their quantities varied significantly among the accessions analysed. Lipid content ranged from 9.5 – 27% (w/w) in the wild accessions while the cultivated contained 20 – 33% (w/w) lipids per dry weight of tubers. The oil quality of wild and cultivated nutsedge tubers was similar, and the oil closely resembles olive oil and a variety of other oil crops. Crude protein content varied among accessions from 7.2 – 13.6% (w/w) with less variability among cultivars (9 – 11%). Starch content showed limited variability in both wild and cultivated nutsedge (30 – 40% per tuber dry weight). A significant proportion of the tuber dry weight consisted of up to 24% of dietary fiber.

Results of the sensory analysis revealed that a mixing of nutsedge flour was considered to enhance the products made. Among the four products tested, cakes, bread and cookies with nutsedge flour incorporated, all were considered better than conventional products. Bread made from a mix of nutsedge/wheat flour was rated as liked very much for its flavor, texture and appearance, and extremely liked for its smell. Furthermore, cookies that had nutsedge flour incorporated in the recipe were the most acceptable of all the baked products and described as being sweet, nutty and aromatic.

Dissemination of results

The results have been shared with students, scientists, farmers and other interested stakeholders in classes, out-reach services, field days, workshops and scientific conferences held in Uganda, Nigeria, Sweden and Kenya. Face to face interactions were also used to share information about the possibility of using yellow nutsedge as a food crop. As an example, after taking part in a symposium on the potential of using nutsedge as a crop, local farmers from the Eldoret area in Kenya expressed interest in getting yellow nutsedge tubers to carry out small scale cultivation trials on their own farms. Tuber material is now multiplied for this reason. Another such interaction was established during sensitisation workshops. The Department of Nutrition and Consumer Studies at the University of Eldoret prepared flour from yellow nutsedge mixed with wheat, maize or sorghum flour, to prepare different food products familiar to Kenyan consumers such as cookies, 'chapattis', porridge and cakes. On field days, both women and men were invited to taste the products.

Three manuscripts on nutsedge are being prepared for publication in refereed journals. One paper report on a set of microsatellite markers (SSR marker), developed in this project and used in analysing the genetic diversity of the yellow nutsedge (*C. esculentus* L.) population in East Africa. A second paper discusses the potential of yellow nutsedge as a new crop in Kenya. The third paper reports on the distribution of, and genetic diversity and resources of yellow nutsedge in East Africa.

Photo: Joice Agalo

Workshop articipants checking for nutsedge nuts at the demonstration plot at the University of Eldoret, Kenya.

> "The program enabled us to show that the yellow nutsedge has the potential to become a new crop with high nutritional value"

Photo: Joice Agalo

Researchers, students and farmers at the Nutsedge demonstration plot during a workshop at the University of Eldoret, Kenya.

Gender aspects

Overall, the project benefited both genders. During its implementation, one female MSc student (Kenya) was trained in plant morphology, cytogenetics and taxonomy. Part of her training took place in Sweden. Another female MSc student (Kenya) took part in the collection of nutsedge accessions. Two female lecturers (Kenya) were given the opportunity of a sabbatical leave from their teaching duties (three and eight years since their PhD exam) to travel to Sweden for three and nine months, respectively, working as post-doctoral researchers with molecular genetics and biochemistry analyses of yellow nutsedge material. The project co-scientists comprised equal gender representation. Both men and women attended the open field days.

Greatest value of the program

The program enabled us to show that the yellow nutsedge has the potential to become a new crop with high nutritional value. Given its nutritional composition and wide distribution in the region, it may contribute to the diversity of food sources and reduce heavy reliance on the few common staples. The project contributed to capacity building of staff that were in the project through staff exchange between Sweden and Kenya. Moreover, two female students at MSc level received hands-on training working with yellow nutsedge. The project exposed farmers to a potential new crop that could have future economic value. Finally, the project has revealed a great genetic diversity and resource of yellow nutsedge in East Africa.

In addition to the successful results on yellow nutsedge, this continuing collaboration with Moi University has also given added value by allowing us to communicate results from an earlier project on sorghum. Three scientific publications have been prepared on physiological and biochemical responses of selected sorghum germplasm to aluminium stress, as well as on the development of molecular markers to identify aluminium stress resistance in sorghum.

A summary of the statistics for this project on p.152

2. Urban and peri-urban livestock farming in Uganda

Goats on the streets of Kampala, Uganda.
Photo: Emil Planting Mollaoglu

Photo: Sofia Boqvist

Female dairy farmer discussing milk recording with staff from the Makerere University.

Synthesis

Global urbanisation is increasing as the global population increases, and this is particularly the case in several African countries currently experiencing rapid economic growth. These factors combined have lead to an increase in demand for food of animal origin, the so called 'livestock revolution'. The solutions to meet this increasing demand, especially in urban and peri-urban (UPU) areas, are to increase the food transported to the cities from rural areas or to produce the food in the areas where people live. On a global scale, UPU agriculture accounts for up to 20% of all food produced in the world, and in low-income countries it is often considerably more. UPU livestock production creates many opportunities for poor small holders to raise money, for example through the close proximity of markets; furthermore women can often combine livestock keeping with household work. Keeping livestock also creates possibilities to re-circulate urban household wastes and waste water, and is an opportunity to provide food of animal origin for the family. Thus, it may represent an important pathway for poverty reduction.

There are, however, three major challenges that represent serious constraints to the further development of UPU livestock production. One is contagious diseases, including zoonotic diseases transmittable between animals and humans. Contagious diseases have a negative impact on animal production and constitute public health risks. The spread of such diseases, and also the emergence of new diseases, is facilitated in areas where there are markets selling live animals and where the densities of both people and livestock are high. Thus, new challenges to control contagious diseases may arise as UPU animal production increases.

Another challenge is feed supply. In UPU areas, farmers have limited possibilities to grow feed for their animals and there are difficulties related to transport and purchase of feed. Therefore, available by-products of varying origin are used as animal feed. However, the quantity and quality of these by-products are usually not sufficient to cover the needs for high producing animals.

A third challenge is manure management. Animals in UPU produce manure that to some extent is used as fertiliser in local crop production, some is bagged and sold and some is left as a pollutant. In the case of Kampala the latter accounts for over 60% of the manure produced. If handled properly manure is a valuable source of nutrients, and can be used for fodder production. All manure management and use pose risks for disease transmission from the manure to animals as well as to humans.

Urban and peri-urban livestock production is important for food security for many small holders in these areas. It is also an important pathway out of poverty. These aspects were addressed by all subprojects under the main project Urban and peri-urban animal farming in Uganda. To solve some aspects of the challenges described above both specific projects and a project involving all three challenges were conducted. The ultimate goal is to increase food security by optimising livestock production in a safe and sustainable way.

Sofia Boqvist (coordinator)

Brucella infections among cattle in urban and peri-urban areas in Uganda

Project leader: Sofia Boqvist

Summary in Swedish

Brucella infektioner hos nötkreatur i stadsnära miljöer i Uganda

Stadsnära djurhållning är viktig för att bidra till livsmedelsförsörjningen för en växande urban befolkning. Det finns dock flera utmaningar med en sådan djurhållning, till exempel sjukdomar som kan drabba djur och människa, så kallade zoonoser. Dessa sjukdomar påverkar livsmedelsproduktion och folkhälsa negativt. Bakteriesjukdomen brucellos, som orsakar aborter och minskad mjölkproduktion hos kor, är en sådan sjukdom. Den smittar vanligen till människa via opastöriserade mjölkprodukter. Detta projekt undersöker förekomst av och risker med *Brucella* bakterier i mjölkkedjan i stadsnära områden i regionerna Gulu och Soroti, Uganda. Båda områdena var tidigare drabbade av allvarliga konflikter vilket har bidragit till en ökad urbanisering. I projektet har även cirkulation av sjukdomsorsakande organismer tidigt i livsmedelsproduktionen studerats samt en hälsostudie av getter och kor i stadsnära miljöer i huvudstaden Kampala genomförts.

Projektet visade att infektion med bakterien *B. abortus* är vanligt förekommande i mjölkkedjan i städer- och stadsnära regioner. Detta har visats genom att mäta förekomst av antikroppar (seroprevalens) hos kor och i tankmjölk som levereras till uppsamlingsplatser. Seroprevalensen av brucellos var vanligare förekommande i Soroti än i Gulu, vilket kan reflektera skillnader i den stadsnära djurhållningen som påverkar spridning och förekomst av sjukdomar. Studien visade även att bakterien utsöndrades i mjölken hos kliniskt friska kor. Detta utgör en viktig folkhälsorisk eftersom en stor andel personer rapporterades dricka opastöriserad mjölk och dessutom hade få eller inga kunskaper om brucellos. Slutsatsen är att zoonotiska sjukdomar har stor betydelse i hela livsmedelskedjan, från gödselhantering till det färdiga livsmedlet. För att få bättre kunskap om dynamiken kring infektionssjukdomar är det viktigt att studera hela livsmedelskedjan.

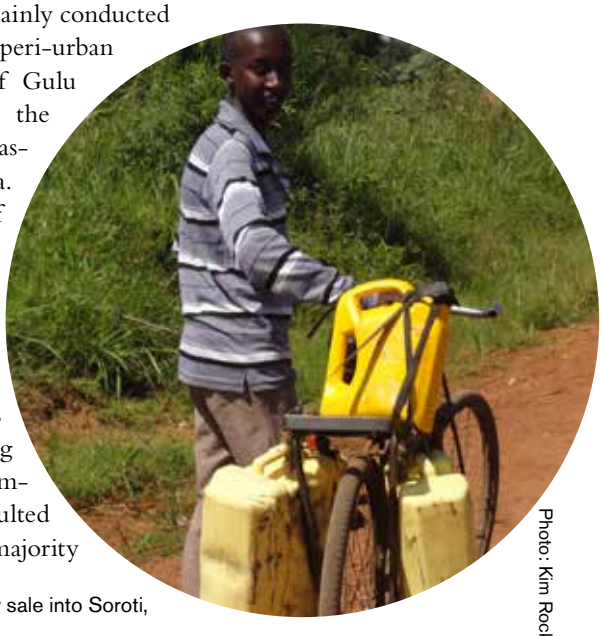
Summary

Keeping livestock in urban and peri-urban (UPU) areas is important to provide food for a growing urban population. There are, however, several challenges with such animal production, for example diseases that affect both animals and humans, i.e. zoonoses. These diseases negatively affect food production and public health. The bacterial disease brucellosis is such a disease and it causes abortions and reduced milk production in animals. It mainly infects humans through unpasteurised milk products. This project investigates occurrence and risk of *Brucella* in the milk chain in UPU areas in Gulu and Soroti regions, Uganda. These regions are post-conflict areas; strife in rural areas led to increased urbanisation. Circulation of pathogenic organisms early in the food chain has also been studied in this project, and a health survey among goats and cows in UPU areas in the capital Kampala has been performed.

The project has shown that infection with the bacterium *B. abortus* is widespread along the milk chain in UPU areas, as measured by presence of antibodies (seroprevalence) in dairy cattle and in bulk tank milk. There were substantial differences in seroprevalence when the two study regions were compared, which may show that the stage of development in transitional UPU farming has an influence on the herd sero-prevalence of brucellosis. The bacteria were furthermore shed in the milk by apparently healthy cattle. This constitutes an important public health risk as unpasteurized milk was reported to be consumed, and the majority of consumers had little or no knowledge about the disease. The overall conclusion is that zoonotic diseases are of importance in the whole food chain, from manure management to the final food product. We also conclude that analyses throughout the whole food production chain is important in order to gain better knowledge about the dynamics of infections within it.

Background

This project was mainly conducted in the urban and peri-urban (UPU) regions of Gulu and Soroti, in the Northern and Eastern part of Uganda. With the onset of civil war in the mid 1980's in the study area, people were moved into internally displaced people's camps, and keeping large herds was impossible. This resulted in the sale of the majority



A boy carrying milk for sale into Soroti, Uganda.

Photo: Kim Rock

of local herds. During the re-settlement period, many government and non-governmental projects provided farmers with exotic breeds which were kept under the UPU farming system, together with local breeds that came from different parts of the country during this re-settlement in and around towns. There are several diseases, including zoonoses (i.e. diseases transmittable between animals and humans) that are particularly important in UPU areas. One is the bacterial disease brucellosis which is a key zoonosis of major public health, animal welfare, and economic significance, and is endemic in livestock in Uganda. It causes reduced milk production and abortions in livestock, and a persistent, debilitating disease in humans. The aim of this project was to address food security and safety challenges in UPU areas. This was done by investigating the informal milk chain risk factors for brucellosis in cattle and in bulk tank milk, and risks of exposure for the consumers. Studies of circulation of pathogens, including zoonoses, early in the food chain, and a health survey of cattle and goats in the Kampala region were also conducted.

Collaborators

This project was developed and carried out in close collaboration with the College of Veterinary Medicine, Makerere University, Uganda. Both the Ugandan and Swedish teams are also involved in *Brucella* research funded by a bilateral Sida program and the projects have benefitted from each other.

SLU

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District Veterinary Officers

Tony Aliro, Tonny Kidega, Gulu, Uganda

Patrick Eyudu, Charles Ariko (assistant), Soroti, Uganda

Other important collaborators are the field veterinarians and village chiefs who assisted with the field work, and personnel working at the three included dairies in Gulu and one dairy in Soroti.

Approach

Field studies were conducted mainly in Gulu and Soroti, but also in Kampala. The samples consisted of blood- and milk collected from dairy cattle and from bulk tank milk collected from milk boiling points, or milk collecting centrals. Fecal samples were also collected in Kampala. Epidemiological data was obtained from farmers, milk deliverers and street milk vendors using written questionnaires. This data was used to analyse the milk chain from production to selling, in order to make models of risk factors for infection at cow- and herd level and to make a general health survey. Serological analyses were performed on the collected samples to investigate the prevalence of antibodies mainly against *Brucella*. In Kampala serological analyses using Enzyme-Linked Immunosorbent Assay (ELISA) for Peste des petits ruminant virus and *Brucella* were performed in goats, and Salmonella, bovine viral diarrhea virus and *Brucella* in cattle. Bacterial cultures of the *Brucella* bacteria were obtained from milk samples and the isolates were subjected to advanced molecular techniques using Multiple Loci VNTR Analysis (MLVA) and Reverse Transcriptase Polymerase Chain Reaction (RT-PCR) to characterise the isolated bacteria. Samples from the bulk tank milk were subjected to molecular analyses using RT-PCR to detect and quantify levels of brucella through detection of nucleic acid. To investigate presence and accumulation of zoonotic pathogens in materials and worms (African nightcrawlers) nucleic acid was extracted from a vermicompost and all genomic material was sequenced using high-throughput sequencing.

Scientific results

In the main project we showed that *Brucella* infection, measured by presence of antibodies, was widespread in the study regions. Antibodies against brucellosis (sero-prevalence) were found in 7.5% of all sampled animals belonging to as many as 27% of all herds included in the study. Interestingly, the sero-prevalence was significantly ($p>0.001$) higher in Soroti than Gulu both at the animal and herd level. This was reflected also in the bulk milk samples; 33 and 11% of the milk samples from Soroti and Gulu, respectively, had antibodies against *B. abortus*. Reasons for the difference between

the regions are probably due to differences in housing and management of the animals. In Gulu, women have the main responsibility for milk production, and this is mainly run intensively on small scale farms having a few cows of European origin. In this region, sero-positivity was significantly ($p>0.05$) associated with an increase in herd size and age, and was higher in cattle from western Uganda. In Soroti town, milk production is mainly extensive with more cows per household, and men have the main responsibility for the cows. The significant risk factors identified for *Brucella* sero-positivity at herd level were introduction of new cattle into a herd, and keeping cattle in isolation from pigs. Overall, there was little knowledge about brucellosis in the community, and the majority of study subjects had not heard of the disease before. *Brucella* bacteria from the individual milk samples were isolated through bacterial culture from apparently healthy cattle. The isolates were identified as *Brucella abortus,* which is the *Brucella* species most commonly isolated from cattle. These animals constitute risks for public health. Molecular typing to further characterise the bacteria is still on-going. We also show that the *Brucella* bacterium is present in milk delivered to consumers, measured by presence of *B. abortus* DNA. Despite the fact that much milk was delivered to designated places where it was boiled, one third of the milk deliverers reported that they consumed unpasteurized milk. These consumers are at risk of being infected by brucellosis.

The general health survey in Kampala showed that antibodies against Peste des petits ruminant virus and *Brucella* were present in goats, and against *Salmonella*, bovine viral diarrhea virus and *Brucella* in cattle at higher or lower levels. Thus, there is also a risk of direct transmission of pathogens between animals and humans in the UPU areas, for example because of poor bio-security and lack of basic hygiene measures. We also show that the risk of transmission of pathogens is of concern, even at the earlier stages in the production chain. That is, in a system in which manure is degraded to fertiliser in a vermicompost, from which the worms can be a potential source of protein feed. When analysing circulation of pathogens in this system, sequencing revealed that a wide range of bacteria were present in both the compost material and in the African night-crawlers (i.e. the worms used for decomposition). As expected, a high number of the bacteria present in the samples belonged to different groups of environmental bacteria. Apart from the latter, a number of the bacterial groups identified contained pathogens to humans and/or animals, e.g. the phylum Firmicutes which includes the class Clostridia, several species of which cause severe and sometimes fatal diseases. The samples also contained different viruses, but to a much lower extent. Studies are in progress to further verify the results from the sequencing and bioinformatics analysis, and to classify the specific members of the bacterial groups identified at this initial stage. Comparative analysis between the microbiome of the different layers in the compost unit may also enable insight of the effect of the composting process on the microbial flora.

The overall conclusion is that zoonotic diseases are of importance along the whole food chain, from production of feed to human consumption. Better understanding of the dynamics and better control of infections along the whole food chain will contribute to increased food security and -safety.

Dissemination of results

Four scientific publications intended for peer reviewed international journals are under preparation; three directly originating from this project and one in collaboration with the Sida funded bilateral project. Two MSc reports (Minor Field Studies) from two Swedish undergraduate students have been published. One poster has been presented at the international conferences organized by the Swedish Research Network: Agricultural Research for Development (Agri4D) in 2012, Uppsala, Sweden. Two presentations

Photo: Kim Rock

A woman farmer with her single cow, Gulu, Uganda.

"On a global scale urban and peri-urban agriculture accounts for 20% of all food production in the world, and in low income countries it is often considerably more"

Photo: Kim Rock

People lining up to purchase small bags of milk in Gulu, Uganda.

were also held at the SLU Africa Food Security Research Symposium, Kampala, 4-6 Dec 2012 and one at the SLU Global Food Security Symposium, Uppsala, 12 -13 June 2013. In 2013, an oral presentation will be held at the Association of Institutions for Tropical Veterinary Medicine (AITVM) International Conference, "The livestock-human-wildlife interface", South Africa. The project has also been presented at several seminars at Makerere University and at SLU. Results will be disseminated in Gulu and Soroti in the autumn 2013 together with dissemination of results from the Sida funded bilateral project. Knowledge transfer of antimicrobial susceptibility testing, advanced molecular analyses techniques and epidemiological modeling have been made researchers at the Makerere University.

Gender aspects

Urban and peri-urban livestock production can be seen as a way for women to gain more income from animal production as they can combine household responsibilities with nearby livestock production. Traditionally men have the responsible for management of cattle, goats and sheep, whereas women have the main responsibility for poultry and pigs. The UPU production systems can have the effect that the role of women in the dairy sector increases. This was seen in the Gulu UPU areas where the majority of dairy cows were kept in zero-grazing systems. Women could thereby combine household work with rearing dairy cattle. This is an important extra income for the family and/or also provides milk and meat for household consumption.

In the project we collaborated with the existing researchers and PhD student within the areas of importance for the project at Makerere University. They were all men, which is a reflection of the current gender distribution at that university.

Greatest value of the program

The greatest value of the programme was that we could strengthen the ongoing research collaboration with Makerere University, and that this and the Sida bilateral project could benefit from each other. Another great value was that we could make an additional pilot study on transmission of pathogens in vermicomposts and show the risk for transmission of zoonotic pathogens in primary production. The results obtained will be used for new research applications. We have also built stronger contacts with the International Livestock Research Institute (ILRI), Kenya. Overall, the programme has given us deeper understanding of the dynamics of an important zoonotic disease in UPU areas in Uganda. The data provided will be used to further address questions on how to improve food security and food safety.

A summary of the statistics for this project on p.153

Feed for livestock in urban and peri-urban areas in Uganda

Project leader: Jan Erik Lindberg

Summary in Swedish

Foder för djurhållning i stadsnära områden i Uganda

Brist på foder är den huvudsakliga begränsningen för djurproduktion och inköp av foder är inte ett alternativ för fattiga hushåll. I städer och stadsnära områden har bönderna ofta begränsad möjlighet att odla eget foder till djuren och det finns svårigheter med att transportera och köpa in foder. Därför utfodras djuren med restprodukter av olika slag. Dock är kvaliteten på dessa foder inte alltid tillräcklig för att husdjuren ska producera bra. Dessutom är det brist på kunskap om hur tillgängliga lokala foderprodukter, så som restprodukter från fodergrödor, kan utnyttjas på ett optimalt sätt.

Vi har, i nära samarbete med forskare på Makerere Universitet, identifierat tillgängliga foderresurser för livsmedelsproducerande djur i Ugandas huvudstad Kampala med omnejd. Insamlade foderprover har analyserats kemiskt och potentiellt energi- och näringsvärde har skattats. Genomförda studier visar att lantbrukarna använder ett antal strategier för att hantera situationer med foderbrist. Merparten av dessa strategier är dock kortsiktiga och inriktade på att klara den dagliga foderförsörjningen, medan det saknas en mer uthållig långsiktig strategi. Våra studier visar också att lantbrukare i Kampala har olika traditionella kriterier för att bedöma fodrets näringsvärde, men att man vid val av fodermedel i första hand går på tillgänglighet och pris.

Genom att bättre utnyttja tillgängliga foderresurser till djur, kan produktionen förbättras, vilket i sin tur ger ett produktionsöverskott. Ett produktionsöverskott kan bidra till en förbättrad livsmedelssäkerhet och ett förbättrat näringsintag för människor i resurssvaga hushåll i städer och stadsnära områden, och kan dessutom bidra till ökade inkomster.

Summary

Lack of feed is the main constraint that limits livestock production; purchase of feeds is usually not an option for poor households. Farmers have limited possibilities to grow feed for their animals in urban and peri-urban areas and there are also difficulties related to transport. Therefore, available by-products of varying origin are used as animal feed. However, the quality of these by-products is not always sufficient to cover the needs for high production. Meanwhile, there is a lack of knowledge on how to make better use of those feed resources that already exists locally, such as by-products from food crops.

In close collaboration with staff at Makerere University, we have identified available feed resources for livestock in urban and peri-urban areas of Kampala, the capital city of Uganda. Collected feed samples have been chemically analysed and their potential energy and nutritive value assessed. Our studies show that farmers have adopted several strategies to cope with feed scarcity. However, most of the coping strategies adopted were short-term, dealing with feed scarcity on a day-by-day basis, while sustainable long-term strategies were lacking. We found that farmers use several indigenous criteria to judge the nutritional quality of the available feed resources, but that availability and cost out-weighed nutritional quality when faced with a choice.

Productivity of livestock can be improved by better utilisation of available feed resources. This would result in a surplus which, apart from generating extra income, could improve food security and nutrition of urban and peri-urban poor people.

Background

Livestock keeping is becoming increasingly popular in Kampala, the capital city of Uganda. This trend can be attributed to the rapid human population growth and urbanisation, increase in the consumer demand for livestock products, and proximity between production and a ready market has lured many into pursuing livestock production. Uganda's urban population was estimated at 3.7 million in 2007 and more than 40% of this population lives in Kampala. The rapid population growth is largely explained by rural-urban migration.

However, lack of feed is a real chal-

Piglet feeding.

Photo: Linn Frendberg

lenge. Since urban farmers lack access to land, the cultivation of forages is almost impossible. Commercial feeds or agro-industrial by-products are often too expensive for these resource-poor farmers. As a coping strategy, livestock farmers use whatever material is available to them i.e. forages on open access lands, leftover food and market crop wastes. However, information on the identity, availability, quantity and nutritional quality of these feed resources is inadequate. Understanding their nutritional quality and availability would be a significant step towards their better utilisation. By better utilising available feed resources, livestock productivity can be improved which would directly contribute towards the improvement of livelihoods of the most vulnerable households keeping livestock in urban and peri-urban areas of Kampala.

Collaborators

SLU

Jan Erik Lindberg (project leader), Emma Ivarsson, Magdalena Presto, Stephanie Kindbom (MSc student), Ulrika Hansson (MSc student), Linn Frendberg (MSc student) – Dept. of Animal Nutrition and Management, Uppsala, Sweden

Makerere University, Kampala, Uganda

Constantine Katongole, Justine Nambi-Kasozi, Felix Bareeba, Richard Lumu (MSc student), Lawrence Kasule (BSc student) – Dept. of Agricultural Production

Approach

Locally available feed resources used by livestock farmers in urban and peri-urban areas of Kampala were identified, collected and chemically analysed to assess their potential nutritive value. Additionally, a large questionnaire survey was conducted in the same areas to identify the indigenous criteria used by livestock farmers to assess the nutritional quality of available feed resources, and to examine the effectiveness of the strategies adopted by livestock farmers to cope with feed scarcity.

A total of 120 households rearing livestock (cattle, goats/sheep, pigs and chickens) from Makindye (34), Kawempe (32), Rubaga (30) and Nakawa (24) divisions were interviewed. They were randomly selected from lists of households rearing livestock, compiled by local leaders, and were contacted in advance on whether they were willing to participate. Those not willing to be interviewed were replaced by other households, which were also picked randomly from the provided lists. From each selected household, the key person involved in the daily feeding of the livestock was interviewed.

Prior to the questionnaire survey, one focus group discussion (FGD) was conducted in each of the four divisions. Each focus group comprised of a total of nine people (six farmers – three females and three males, two local leaders and the livestock extension worker of the division). The FGDs were helpful in identifying the most important livestock feed resources and farmers' indigenous criteria of assessing (judging) the nutritional quality of the feed resources for cattle, pigs and chickens.

Scientific results

Results showed that dairy cattle (48.3%) and chickens (37.5%) were the most common species, followed by pigs (34.2%), goats (26.7%) and sheep (3.3%). Farm size was generally small both in terms of herd size and total landholding. Banana peels (*Musa spp.*) as well as elephant grasses were the most commonly used feed resources among cattle farmers. Left-over food and banana peels were the most commonly used feed resources among pig farmers, while most of the chicken farmers used own-mixed feeds in preference to the commercially mixed feeds. Farmers use several indigenous criteria to judge the nutritional quality of the available feed resources. These included perceived effects on disease resistance, feed intake, growth/body condition, hair coat appearance, faecal output, faecal texture, and level of production among others. According to farmers, animals offered a feed resource of good nutritional quality are more resistant to diseases, ingest much of the feed, gain weight with well filled bodies, have smooth hair coats, produce large quantities of faeces that are not too firm or watery, and exhibit good performance (lactating cows produce more milk, sows produce piglets of good body size, hens lay more eggs of normal size etc.). Although this indigenous knowledge exists, farmers put more importance on availability and cost as opposed to nutritional quality when choosing feed resources. This explains why banana peels were among the feed resources perceived to be of low nutritional

quality, but at the same time were found to be the most commonly used. Hence, sensitising farmers in urban and peri-urban areas of Kampala on the importance of nutritional quality would result in better and efficient utilisation of available feed resources.

Cattle and pig farmers in urban and peri-urban areas of Kampala ranked feed scarcity as their first major constraint, while chicken farmers had high cost of feeds. These farmers have adopted several strategies for coping with feed scarcity. Among the major coping strategies adopted were: changing of feed resources based on availability and cost (37.5%), purchasing of feed ingredients in bulk (29.7%), using crop/food wastes (26.6%), harvesting of forages growing naturally in open access lands (23.4%) and reducing herd size (17.2%). However, most of the coping strategies adopted were largely aimed at dealing with the perennial challenge of feed scarcity on a day-by-day basis rather than dealing with it using sustainable and long-term strategies. In view of this, farmers should be encouraged to adopt coping strategies that can deal with the perennial challenge of feed scarcity more sustainably.

Following the observation that the majority of chicken farmers in urban and peri-urban areas of Kampala mix their own feeds in preference to the commercially mixed feeds, a study was undertaken to assess the nutritional properties of own-mixed chicken rations. Eight samples of each of the five commonly used chicken rations (broiler starter, broiler finisher, chick mash, grower mash and layer mash) were collected and analysed for nutrient content and gross energy, and their content of apparent metabolisable energy (AMEn) was calculated. The nutrient content and AMEn of the rations were compared with dietary requirements recommended for chickens in the tropics. Results showed that all the five chicken rations contained lower crude protein content than the minimum dietary recommendations. Broiler rations contained lower AMEn than the minimum dietary recommendation, while their crude fibre content was higher than the maximum dietary recommendation. Layer mash contained lower calcium content and AMEn than the minimum dietary recommendations. All the five own-mixed chicken rations were very high in ash content. It was concluded that own-mixed chicken rations do not meet nutrient requirements. The rations are low in crude protein, calcium and AMEn, but high in crude fibre and ash. Their nutritional inadequacy is attributed to the combination of improper feed formulae, and use of low quality (as a result of adulteration) feedstuffs, particularly fish meal (*Rastrineobola argentea*) locally known as Mukene. Therefore, giving farmers training on feed formulation and how to source good quality feedstuffs would result into enhanced chicken productivity.

Dissemination of results

The major findings of the project have been published in three separate scientific papers in peer-reviewed international scientific journals, and one more scientific paper is in the manuscript stage. In addition, the data collected in the project has been used for one BSc thesis and one MSc thesis at Makerere University (Kampala, Uganda), and three BSc theses in Animal Science at SLU (Uppsala, Sweden).

A course in "Comparative Animal Nutrition" was given by the Department of Animal Nutrition and Management, SLU, in November 2011 at Makerere University in Kampala. The course was attended by 19 Ugandan students (18 MSc Animal Nutrition, 1 PhD Animal Science). The course was organised and hosted by the Department of Agricultural Production (Makerere University).

An initial project co-ordination workshop was conducted in Kampala (April, 2011). This was fol-

Photo: Linn Frendberg

Pig housing.

"Cattle and pig farmers in urban Kampala ranked feed scarcity as their major constraint"

Photo: Linn Frendberg

Collecting food waste.

lowed by an inception workshop for stakeholders at Makerere University (6th and 7th July 2011). The main objectives of the inception workshop were to: i) inform key stakeholders about the project "Feed for livestock in urban and peri-urban areas in Uganda"; ii) inform the key stakeholders about their roles and level of participation in the project; and iii) interact with key stakeholders and obtain their input to the project. A dissemination Conference with invited farmers and stakeholders was held at Makerere University (7th December 2012). The aim of the dissemination workshop was to share the project findings with different stakeholder groups (farmers, local leaders, extension workers, urban authorities etc.). A recorded and edited footage of the dissemination conference was broadcasted by one of the local television stations (WBS Television).

Brochures for extension workers and farmers on feed resources and their utilisation for chickens, dairy cattle and pigs have been produced (in two languages, i.e. English and Luganda – local language). In addition, a farmers' handbook entitled "Availability, Utilisation and Nutritional value of Urban/Peri-urban Livestock Feed Resources: A Farmers' Handbook" is under production. Last but not least, a feed composition data-base will be compiled and published on the Makerere University and SLU web-sites.

Gender aspects

The research team from SLU and Makerere University (active in the project) was comprised of both males and females. The students from SLU were all females, while the students from Makerere University were males. The key stakeholders (farmers, extension workers and local leaders) of the project have been both males and females, but with a majority of females amongst the farmers. The participants in the dissemination conference were dominated by females.

The majority of resource-poor livestock farmers in urban and peri-urban areas of Kampala are females. Therefore, it is crucial to reach this group of farmers with information, which they can use to improve their livelihoods.

Greatest value of the program

Thanks to the program, it has been possible to establish a close collaboration between researchers in Animal Science at SLU and at Makerere University that had not previously existed. This opens new opportunities for future collaboration with regard to capacity development in Sweden and Uganda, and with regard to joint research and development projects.

A summary of the statistics for this project on p.154

Manure management

Project leader: Björn Vinnerås

Summary in Swedish

Från gödsel till foder: gödselhantering i stadsnära områden i Kampala

Urban djurhållning är i många låginkomstländer ett bra sätt för familjer att både förstärka hushållkassan och att förbättra familjens matförsörjning. Samtidigt ger djuren bra stöd i avfallshanteringen i städerna, då matavfall från hushåll, industri och marknader är en stor del av djurens foder. Detta projekt har utvärderat möjligheten att bryta smittspridning via gödselhanteringen i urbana lantbruk som håller djur genom att introducera en värdekedja där foderproteiner produceras från gödseln. Gödselhantering i städer i låginkomstländer är en utmaning eftersom det sällan finns etablerade vägar för hanteringen av djur- och humangödsel. Vissa använder sin gödsel i odlingen, men oftast ligger odlingen inte på samma ställe som gödselproduktionen och det saknas infrastruktur för att hantera den. I Kampala, Uganda, dumpas över 60% av djurgödseln och ännu mer av latrinavfallet (människogödseln) i vattendragen. Genom att omvandla gödsel till proteiner, antingen genom kompostering med mask eller med svart soldatfluga (black soldier fly, BSF), ökar värdet på gödselhanteringen. Behandlingen är även ett sätt att minska risken för smitta, speciellt BSF behandlingen ger en stor reduktion av salmonella i materialet (>99,9999%).

Fördelen med fluglarverna är att de snabbt kan omvandla stora mängder organiskt material, samtidigt är de inte känsliga för sin omgivning, som kompostmaskarna är. När larverna har utvecklats till sista larvstadiet, så kallade förpuppor, lämnar de kompostmaterialet för att finna en torr och mörk plats att förpuppas på. Genom systemets design är det möjligt att leda förpupporna till en uppsamlingsenhet för förvaring innan de förädlas vidare till foder. De viktigaste resultaten visar att det är möjligt att kontinuerligt omvandlat ett kilo gödsel per dag till 100 gram prepuppor, avsedda som djurfoder. Dessutom fann vi att man i en maskkomposteringsenhet kunde omvandla gödsel till ett koncentrerat gödningsmedel och maskbiomassa. I pilotstudier i Kampala, Uganda, omvandlades 500 kilo nötgödsel till 50 kilo maskbiomassa, som kan användas till foder, och 100 kilo kompost, som kan användas som gödningsmedel. Slutsatsen man kan dra från detta projekt är att genom förändring av gödslets värdekedja är det möjligt att konvertera gödseln till värdefullt foderprotein samt att behandlingen i sig resulterar i ett minskat smittryck i miljön.

Summary

Urban animal agriculture is a viable measure for improving household economy, as well as improving the nutritional status of home owners, in low-income countries. This project evaluated the possibility of breaking the transmission of disease from manure management systems in urban animal agriculture by introducing a novel value-chain in the management system that includes production of feed protein from the manure. Keeping animals is a support for waste management in urban centres, as food waste from households, industry and markets is an important constituent in animal feed. On the other hand, manure management is a challenge due to the lack of reliable infrastructure. Some of the manure is used in cultivation, but fields are most often not located at the place where the manure is generated. Due to the aforementioned lack of infrastructure and awareness, it is difficult to establish proper manure management in an urban centre such as Kampala, the capital of Uganda, where over 60% of animal manure and even more of latrine waste (human manure) is discarded into water recipients. By converting the manure into proteins, using either earthworms (vermicomposting) or larvae of the black soldier fly (BSF), the economy of manure management can be greatly improved, while at the same time reducing the risk of spread of disease – both vermicomposting and BSF treatment have been demonstrated to substantially reduce the concentration of salmonella in the material, but the BSF treatment appeared particularly promising in that aspect (>99.9999% reduction).

Other benefits of BSF treatment are their high tolerance to environmental factors (as opposed to worms that are more sensitive) and their capacity to rapidly convert large amounts of organic material. In the final larval stage, the so-called prepupae leave the material in order to

Photo: Sara Eriksson

African black soldier fly pre-pupae.

find a dry and dark place to pupate. The system can be designed in such way that the prepupae are directed to a collection unit, before they are further processed into feed. The strength of the vermicomposting system is the simplicity in installation and implementation. The main findings were that: one kg manure can be transformed into 100 gram prepupae, usable in animal feed, in a continuous BSF-reactor; vermicomposting is efficient for transforming manure into fertiliser and worm biomass. In Kampala, Uganda a pilot system converted 500 kilo cattle manure into to 50 kilo worm biomass, which may be used in animal feed, and 100 kilo compost that can be used as fertiliser. The overall conclusion was that the manure value chain, in which manure can be converted into feed protein, is very attractive for urban animal farming and that this can have good impact on reducing the disease burden of the system.

Background

Urban agriculture is an important source of food for urban dwellers, as the lack of adequate infrastructure in many low-income countries results in large losses in the pre-sales section of the food distribution chain. Urban agriculture is also an important source of income and nutrition to urban dwellers. Unfortunately, animal farming in urban centres poses risks for disease transmission, especially zoonotic diseases that can be transferred between humans and animals. One of the main sources of transmission is animal manure which, in many cases, is not properly managed, as many of the urban animal farms are more or less land-less. At the same time, protein rich animal feed is scarce in many of these areas and in most cases too expensive to be included in sufficient amounts in animal feed mixtures. By introducing local protein production through insect- or vermicomposting a new niche of urban agriculture has been created, encompassing both considerably improved animal feed compositions as economic driving force for proper manure management.

Collaborators

SLU

Björn Vinnerås (project leader), Cecilia Lalander, Allan Komakech (PhD student, also at Makerere University), Maria Elisa Magri (PhD student, also at Federal University of Santa Catarina) – Dept. of Energy and Technology

Sofia Boqvist, Anne-Lie Blomström, Ellen Jönsson (MSc student), Linn Lernfeldt (MSc student) – Dept. of Biomedical Sciences and Veterinary Public Health

Jan-Erik Lindberg – Dept. of Animal Nutrition and Management

Swiss Federal Institute of Aquatic Science and Technology (EAWAG), Dübendorf, Switzerland.

Stefan Diener (BSF expert), Dept. of Water and Sanitation in Developing Countries (SANDEC)

Christian Zurbrügg (Director), Dept. of Water and Sanitation in Developing Countries (SANDEC)

Makerere University, Kampala, Uganda

Technical personnel at MUARIK – Agricultural Research Institute Kabanyolo (MUARIK)

Allan Komakech (PhD student, also at SLU), Dept. of Agriculture and Biosystems Engineering

University of British Columbia (UBC), Canada.

Geoff B. Hill (PhD student at the time of collaboration) – Dept. of Geography

Federal University of Santa Catarina, Brazil

Maria Elisa Magri (PhD cand) – Department of Sanitary Engineering

The BSF treatment was performed in collaboration with EAWAG/SANDEC, as they are one of the leading institutions in Europe working with insect assisted waste management. Manure management by vermicomposting was partly performed in collaboration with UBC.

Approach

Two main studies were performed, of which the first part was a baseline study of current organic waste and manure management in Kampala. This was performed by GIS mapping all animal farms in the City of Kampala. Waste reaching the official landfill was monitored over one year in order to understand and quantify the flow of organic material. The second study focused on protein production from manure: in one study composting with the larvae of the black soldier fly (BSF) and in another with earthworms. The BSF composting study was conducted on lab scale in Sweden, while a case study of vermicomposting was set up at Makerere University Agricultural Research institute, Kabanyolo (MUARIK) in Kampala. The focus of these studies was the hygienic standard

of the end products as well as process engineering aspects for optimised protein production.

Scientific results

When mapping the animals farms within the city of Kampala if was found that their distribution over the city was uneven; a larger number of animals farms was found in peri-urban areas, which have a higher proportion of migrants from the surrounding countryside. The uneven distribution resulted in a large difference in number of animals counted compared to other studies, which had covered only selected sections of the city. Most urban farms did not have large areas of arable land, leading to either high ratio of imported feed or leaving the animals scavenging for feed around the city during day time. Furthermore, most of the generated manure was not managed properly, with over 60% of it being discarded. Animal farms having arable land used their own manure as fertiliser within the farm and in some cases, when animal farms did not have arable land; the manure was transported back to the farms in outer peri-urban and rural areas. The two main findings from this study are: 1) new incentives for farmers for increased manure management are required; 2) the urban animal agriculture is an important part of the organic waste management, as organic waste is the main component in the total waste generated in the city.

The land-less animal farms in Kampala is generally small in size, and contain few animals. A pre-requisite for peri-urban farmers to start managing their manure is the development of a simple and economically viable manure processing system. One way of doing this is by introducing small vermicomposting units, designed for worm production. In a vertically fed system (1 m^2) started with approximately 2,000 worms and fed 5-10 kg cattle manure per day, over 60% of the material was degraded while 4% was converted into worm biomass. The treated compost was stabilised and could be used as fertiliser. Additionally, the contaminated material was contained in treatment for sufficient time to allow for a reduction in the concentration of potentially pathogenic microorganisms, and an active reduction of pathogenic zoonotic bacteria such as *Salmonella spp*. It was further demonstrated that over a period of three months it is possible to convert 500 kg of cattle manure per square metre into around 200 kg fertiliser and over 25 kg earthworms, containing around 70% protein, a potential animal feed.

Protein production with BSF composting requires a larger management system, as it requires both a treatment and a rearing facility. Eggs or young larvae are placed into the treatment unit in which they consume large amounts of organic matter. The intention is to degrade the organic material and harvest the prepupae, which can be used as protein feed in animal production. The adult fly is not interested in food or any sort of organic material as it not has a mouth and hence does not feed, it is therefore not a vector for disease as is the common housefly. Additionally, the BSF larvae act as an inhibitor for oviposition of other flies in the material, lowering the risk for vector transmission of diseases even further. The BSF treatment favours substrates containing more easily available organic material, compared to the vermicomposting unit, and suitable feeds are food waste and manure from humans, chicken and pigs. Together with a high degradation of organic material the larvae reduce the content of intestinal bacteria in the material, with a particular high reduction of the pathogen salmonella during the treatment i.e. - 99.99999% reduction during eight days of treatment. The prepupae, the last larval stage, crawl out of the treatment unit in the search for a dark and dry place

Foto: Björn Vinnerås

Vermicomposting for earthworm production.

"Over a period of three months it is possible to convert 500 kilo cattle manure into around 200 kilo fertiliser and over 25 kilo of potential animal feed"

Photo: Björn Vinnerås

Urban livestock in central Kampala, Uganda.

to pupate. With an appropriate design a treatment unit in which prepupae are self-harvesting could be constructed for the production of animal feed.

Dissemination of results

Scientific publications

Two published/in press, three submitted, two manuscripts, one MSc-thesis manuscript; two scientific conference presentations (outside the two conferences held within the program; *The SLU Africa Food Security Research Symposium, Kampala 2012* and *The SLU Global Food Security Resaerch Symposium, Uppsala 2013*).

Popular science publications

Two radio interviews (Lokalradio Uppland, Västernorrland), one page in local newspaper science section (UNT).

Top story in newsletters

OmVärlden: www.sida.se/OmVarlden/Varlden/Briefing/Fluglarver-forvandlar-dynga-till-djurfoder/
Uppsalanyheter.se http://uppsalanyheter.se/nyheter/oevrigt/item/1563-godsel-blir-djurfoder

Outreach material

Instructional material on how to manage a manure management vermicomposting unit in English is under translation to Luganda.

Commercialisation

Vermicomposting units developed at MAURIK research station has been handed over to the technicians that were running it during the project period and who now run the system as a commercial worm production unit (the first in Kampala).

Gender aspects

The core group of the project have consisted of one female and two males. In the larger collaboration group there were one female MSc student, one female PhD candidate and one male post doc.

Greatest value of the program

The program made it possible to initiate the development of a conceptual idea that had been discussed in the group previously and involved combining two concepts: 1) breaking in the chain of disease transmission; 2) producing animal feed protein directly from the waste. This grant made it possible to endeavor into this high risk project. The results exceeded our expectations. The timing turned out to be excellent as discussions on insect assisted food and feed production attracted considerable attention among the general public during the past year.

A summary of the statistics for this project on p.155

3. Innovative crop protection in eastern Africa

Coffee shredding in Kenya.
Photo: Mattias Jonsson

Photo: Mattias Jonsson

Kenyan landscape – on the left a simple agricultural area with monocultures, on the right a complex agricultural landscape with mixed cropping.

Synthesis

Many Africans are engaged in crop production and many of them do so on a rather small scale. Unfortunately most of the farmers do not achieve the potential yield of their crops. The causes of low yields include poor management, poor soil fertility, low yielding varieties, and damage due to insects and diseases. Many farmers do not take action to control the damage caused by pests and diseases because of lack of knowledge or lack of resources. There are also few available options to chemical pesticides and this has highlighted the need for alternative control approaches. The aim of this project was to explore non-pesticide based solutions to plant protection problems through joint scientific research between Swedish and African partners.

One important component of disease management is the use of resistant crop varieties. Everywhere potatoes are grown in the world the disease potato late blight is a problem. Although potato varieties that are at least partially resistant to late blight are known, it is important to understand the pathogenicity factors within the pathogen population that may be responsible for a breakdown of resistance. New, more aggressive genotypes of the pathogen have been detected in different parts of the world and a survey of the clonal lineage of the pathogen found in different parts of East Africa was undertaken in this project. Aggressive genotypes have completely taken over in Ethiopia, Kenya and Eastern Uganda.

Management and forecasting of some insect pests can be achieved by understanding their chemical ecology and applying knowledge about semio-chemicals (chemicals that provide information to the insect). Progress has been made toward developing trapping methods using blends of odors attractive to the African invasive fruit fly which is a devastating pest of fruit crops. Control through sanitary methods (removal of fallen fruit) was shown to be effective. The potato tuber moth has recently shifted from potato to tomato in Ethiopia. By studying different plant species as possible companion plants in mixed cropping schemes it should be possible to find plants that repel the pest (push) or attract natural enemies of the pest (pull) and develop a "push-pull" design that provides good pest control without pesticides.

Local management activities such as planting shade trees in coffee plantations or using mixed cropping in maize may offer pest management solutions. The efficacy of these methods may, however, be dependent on elements in the landscape because the surroundings may contain reservoirs of pests (diminishing the effect of local management) or sources of natural enemies (enhancing the effect of local management). Although push-pull/mixed cropping resulted in lower damage and higher yields in maize the general pest level was usually lower in landscapes with low occurrence of wild grasses. In coffee, shade kept away some pests (coffee berry borer) while attracting others (stem boring beetles). Knowledge of the most important pests in an area is essential in designing local management.

The results of this project form an important contribution to innovative solutions to pest problems in Eastern Africa. The fact that capacity development and research cooperation have been at the core of this project means that work towards the goals of higher yields and environmentally sound pest control will continue in the future.

Barbara Ekbom (coordinator)

The importance of landscape and local factors for biological control

Project leader: Barbara Ekbom

Summary in Swedish

Betydelsen av landskapet och lokala faktorer för biologisk bekämpning

Detta projekt syftade till att undersöka betydelsen av landskapets utformning och alternativa brukningssystem för en förbättrad biologisk kontroll av skadedjur. Två olika odlingssystem studerades, dels kaffe som är en perenn gröda, och dels majs som är en annuell gröda. För kaffe som odlingssystem undersöktes hur graden av skuggning i kaffeodlingar påverkade förekomsten av skadedjur och deras naturliga fiender. Vidare hur skuggningens påverkan varierade med trädtäckning i det angränsande landskapet samt med avståndet mellan odlingar och naturliga miljöer. För majs som odlingssystem undersöktes effekten av samodling med andra växtslag på förekomsten av skadedjur, samt hur denna effekt påverkades av andelen gräsmark i det omgivande landskapet runt majsodlingarna.

Resultaten från dessa studier visar att landskapet runt både kaffe- och majsodlingar har en tydlig påverkan på de åtgärder, skuggning och samodling, som används för att minska angreppen från skadedjur. Bland annat visade studierna att mångfalden av naturliga fiender till skadedjur på kaffeplantor var högre i skuggade områden med närhet till naturliga miljöer. I majsodlingar där man samodlade med andra växtslag var angreppen från skadedjur betydligt mindre än i odlingar med enbart majs. Studien visad även att vissa grässlag i omgivande gräsmarker utgjorde en reservoar för skadedjur på majs.

En slutsats från denna studie är att valet av brukningssystem för att förbättra den biologiska kontrollen av skadedjur bör göras utifrån förhållanden i det omgivande landskapet.

Kapacitetsutveckling har också varit en viktig komponent i forskningsarbetet och fyra masterstudenter (två svenska och två afrikanska) kommer att utexamineras som en följd av detta projekt.

Summary

This project aimed at investigating the importance of interactions between landscape context and management options for improving biological control of insect pests. Our study included two cropping systems, coffee and maize; one perennial and one annual crop. In coffee cropping systems, we investigated how levels of shading affected abundance of pests and their natural enemies. In addition we also investigated how the effects of shading varied with tree cover in the surrounding landscape and with distance to natural areas. In maize cropping systems we investigated how mixed cropping, as opposed to single cropping, affected pest abundance, and how the proportion of grasslands in the surrounding landscape altered this effect.

The results from these studies show that the effects of management options, shading and mixed cropping, on biological control of insect pests were dependent on factors in the surrounding landscape. In coffee plantations, for example, the diversity of natural enemies to insect pests was higher in shaded cropping areas, given proximity to natural areas. In maize we found that mixed cropping was a valuable management component that kept pest levels low. The studies also showed that specific types of grass in surrounding grasslands served as a reservoir for maize pests.

One conclusion from this project is that in improving the efficiency of biological control of insect pests, management options should be chosen on basis of important factors in the surrounding landscape.

Capacity devlopment has also been an important component in our research and four MSc students (2 Swedish and 2 African) will be able to complete their MSc degrees as a result of this project.

Background

We explored the importance of landscape context and management options for enhancing productivity and resilience under an increasingly variable climate. The focus of our study was on mechanisms that enhance biological diversity and show potential for improving biological control of insect pests. Biological

MSc student Anthony Ijala collecting coffee berries.

Photo: Mattias Jonsson

pest control is one ecosystem service that is threatened by agricultural intensification. For example, the diversity and abundance of natural enemies and natural enemy attack rates have often been found to be lower in landscapes dominated by agriculture. However, such results are not universal and we still know little about the mechanisms behind landscape-pest control relationships. Moreover, the relationship between natural enemy diversity and biological control is far from straightforward. Even though a recent meta-analysis showed that increasing enemy diversity usually strengthens prey suppression, individual studies have found positive, neutral, and even negative multi-enemy effects on prey suppression. We also don't know to what extent natural enemy biodiversity can provide an insurance against fluctuating environmental conditions. We studied relationships between agricultural land-use at different scales and the structure, diversity and variability of natural enemy-pest relationships.

Collaborators

SLU
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icipe (International Center for Insect Physiology and Ecology), Nairobi, Kenya.
Charles Midega, Juliana Jaramillo

Approach

Stemborers on maize and coffee berry borers on coffee are important pests and provided us with a focal point, but other insect pests, especially in coffee were also considered (lace bug, aphid, leafminer, white stem borer). Farms were identified in different areas of Kenya and Uganda. We used available GIS maps combined with ground-truthing to measure important landscape variables such as proportion of grasslands around maize fields and forested areas within a certain radius around each coffee farm. Farms were visited during the cropping seasons and inventories of the biodiversity of natural enemies as well as insect pest pressure were carried out. At the time of the visit, local elements of the farm, such as mixed cropping for maize and shading for coffee, were recorded. Coffee farmers in Kenya were interviewed to determine their attitude towards shade trees in their plantations. In order to carry out successful inventories students attended training session at *icipe* facilities in Kenya, consulted with local advisory services and the individual farmers. Data was analysed to determine the relationship between management, landscape elements and pest pressure.

Scientific results

Coffee/general results

The utility of using shade as a local management strategy against coffee pests will first of all depend on the target pest. Shade tends to offer some protection from coffee berry borer, but sun exposure may decrease attacks of borers in the trunks of the trees and foliage pests. The landscape context is particularly important for foliage pests. Natural enemies may be enhanced in shaded coffee in some landscapes. Ten farmers were interviewed and of those nine had actively planted shade trees on their plantations. All the farmers perceived the coffee berries in the shade to be healthier and more abundant than those in the sun. Seven farmers used the shade trees to also provide goods for consumption and sale.

Coffee/Foliage pests

The pest survey revealed that there was a signi-

Photo: Anna Lehrman

Participants at workshop in Uppsala September 2012

ficantly higher abundance of lace bugs in shaded sites. In contrast, shade had no significant main effect on aphid or leafminer abundance. Landscape composition did not show a significant main effect on the abundance of these pests. However, there was a non-significant trend towards higher abundance of leafminers and lace bugs in sites surrounded by more complex landscapes. The interaction between local management and proportion of tree cover in the landscape was significant for lace bugs, for leafminers the interaction between local management and proportion of semi-natural habitat was significant and for aphids both these interactions were significant. Three of these four interactions indicate that local shading has the highest effect in landscapes where the proportion of semi-natural habitat (for example grass-, shrub-, and woodlands) was low.

Coffee/beetle pests

It was found that irrespective of distance from natural areas, shading reduced abundance of the coffee berry borer but increased the abundance of white stem borer, which can kill trees. Abundance and biodiversity of natural enemies of the coffee berry borer was higher in the shade and biodiversity was enhanced when close to natural areas. Near proximity to natural areas may facilitate biological control as biodiversity was highest there. The areas nearest to a nature reserve were also at the highest elevations and this confounding factor should be studied.

Maize

Cropping system was very important for the level of pest attack by stemborers in maize. In both Kenya and Uganda it was shown that mixed cropping had lower levels of damage and lower levels of stemborer abundance than a monocrop of maize. Yields were clearly higher in mixed cropping than in monoculture. Biological control in the form of parasitisation of stemborer larvae was higher in mixed cropping in both countries. In Kenya a special design of a mixed cropping system called the push-pull system was studied while in Uganda the most common mixed cropping system was beans and maize. There was a trend that indicated a possible effect of landscape context. Damage and occurrence of larvae were higher in landscapes that had some grassland cover compared to areas where there was almost no grassland cover. In order to ascertain the possible contribution of different wild grasses to pest pressure a survey of stemborer occurrence on wild grasses in Uganda was conducted. It was shown that elephant grass and sugar cane were the wild grasses that contained almost as many stemborers as maize crop plants. The results show that mixed cropping is a management option that will consistently provide better plant protection than monocultures of maize. In a landscape context pest attacks could be reduced by removing some grassy areas.

Dissemination of results

The main transfer took place as capacity development. Students had a chance to interact with senior scientists. A planning workshop with the senior scientists took place in Uppsala at the beginning of the project. Visits were made by Swedish scientists to Uganda and Kenya to look at field sites and discuss logistics. A two-week workshop was organised and the Masters students together with senior scientists met in Uppsala in September 2012. The students brought their data with them and everyone was involved in analy-

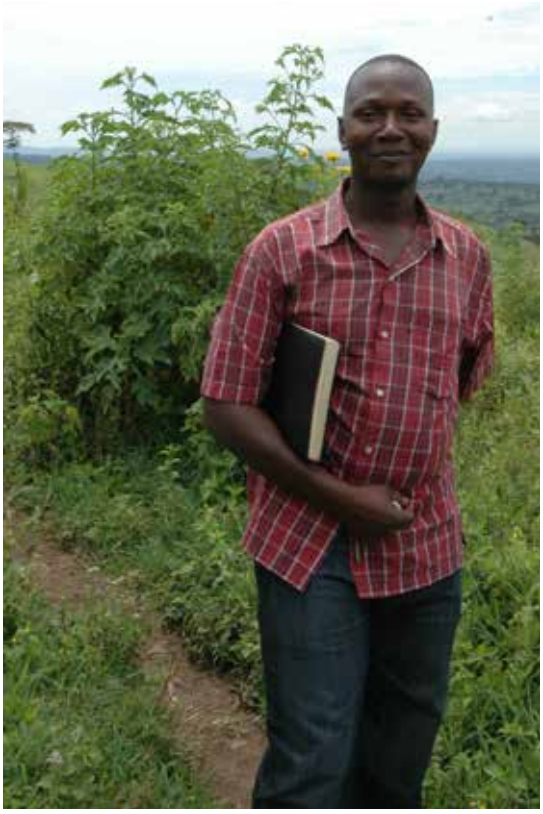

Photo: Mattias Jonsson

MSc student Dennis Gayi looking for appropriate field sites for maize experiments.

> "The results from the scientific studies will also provide information for advisory services and for farmers"

Photo: Mattias Jonsson

MSc students Nina Backlund and Louise Malmberg talk with farmers on a coffee plantation.

sing the data. The students learned new statistical techniques and GIS. At the end of the workshop the students presented their results for the Department of Ecology and other invited guests. The students received feedback on their projects and the audience was informed about the work in Eastern Africa. Working at over 40 field sites meant that the students were required to interact with farmers and advisors in Africa. Farmers on coffee farms in Kenya participated in interviews on their awareness of pest pressure on their farms and their perception of using shade trees as a management measure. The two Swedish students have completed their projects and their reports are available. The two Ugandan students will complete their Masters degrees at the end of 2013. One publication from a study in Uganda and a book chapter about the interaction between landscape and local factors has been published. We are currently working on four joint manuscripts that will be published early in 2014.

Gender aspects

Both men and women have been represented in approximately equal proportions among both the scientists and PhD students.

Greatest value of the program

We have shown that it is possible to use a theoretical approach based on ecological principles to generate hypotheses and experimental designs that will answer important questions concerning management and land use in agriculture. The results from scientific studies will also provide information for advisory services and farmers. Students have been instructed in this approach and will be able to use it when studying important questions for improved agriculture in the future. Our results clearly highlight the need to consider both local management and landscape management when designing pest suppressive and sustainable agricultural environments. In coffee, cropping systems knowledge about the most important pests will guide the choice between sun exposed and shady environments. Closeness of non-agricultural environments has the potential to enhance natural enemy communities. In maize, mixed cropping and especially the push-pull system is very effective in reducing pest numbers and increasing yields. Wild grasses in proximity to fields may contribute to higher pest attack.

A summary of the statistics for this project on p.156

Epidemiological studies to determine the impact of resistance in controlling plant diseases

Project leader: Jonathan Yuen

Summary in Swedish

Epidemiologiska studier för att mäta effekten av växtresistens som kontrollåtgärd mot växtsjukdomar

Phytophthora infestans orsakar bladmögel på potatis och tomat. Under 1900-talet har en specifik förhärskande variant av *P. infestans* orsakat skador på odlingar av dessa grönsaker i stora delar av världen. Nya, mer aggressiva varianter har etablerat sig vilket fått till följd att användningen av bekämpningsmedel har ökat. I Afrika söder om Sahara fanns fram till nyligen inte dessa nya varianter. Syftet med detta projekt var att kartlägga spridningen av nya varianter av *P. infestans* i Etiopien, Kenya och Uganda. Detta har gjorts genom att samla in ett stort antal prover av växtmaterial från potatis och tomat och med hjälp av genetiska metoder bestämma den regionala förekomsten av de olika varianterna.

Resultaten visar att den tidigare förhärskande varianten av bladmögelpatogenet inte längre kunde hittas i Etiopien och Kenya och att den har ersatts av en ny mer aggressiv variant. Prover från Uganda uppvisade en gradvis skillnad från öst till väst, där den nya varianten var mer vanligt förekommande i de östliga delarna av landet, vilket indikerar en pågående förskjutningsprocess.

En slutsats från dessa studier är att en mer aggressiv variant av bladmögelpatogenet *P. infestans* har och håller på att etablera sig i afrikanska länder söder om Sahara. Detta kommer sannolikt att försvåra bekämpningen, öka användandet av bekämpningsmedel, och skapa såväl ekonomiska som miljömässiga utmaningar för resurssvaga jordbrukare i dessa regioner.

Summary

Phytophthora infestans is the causal agent of late blight on potato and tomato. In most parts of the world during the 20th century a specific predominant variant has caused damage by infecting these vegetables. The establishment of new, more aggressive variants has required an increased use of fungicides. Until recently, countries in sub-Saharan Arica have been spared of the new variants. The aim of this project was to survey the dispersion of new variants of *P. infestans* in Ethiopia, Kenya and Uganda. For this purpose, a large number of plant samples from potato and tomato were collected, and subsequently analysed using genetic methods to assess the regional distribution of the different variants.

The results showed that the earlier predominant variant could no longer be found in samples from Ethiopia and Kenya. Instead, these samples showed that it had been replaced by a new, more aggressive variant. In Uganda, samples exhibited a gradual change from east to west, with the new variant more commonly identified in the eastern parts of country. This finding indicates an ongoing displacement process.

One conclusion drawn from these studies is that a new, more aggressive variant of the late blight pathogen, *P. infestans,* has become established in sub-Saharan Africa. Most likely, this will cause increased difficulties in controlling late blight infections and increase the use of fungicides. As a consequence, resource-poor farmers in these regions will experience both economic and environmental challenges.

Background

Potato is an important crop in parts of East Africa, and is a highly valued crop in an area consisting of Burundi, Rwanda, southwestern Uganda, and the Democratic Republic of the Congo (Lake Kivu region). These potatoes, as in the rest of the world, are susceptible to potato late blight, caused by *Phytophthora infestans*. Likewise, as in the rest of the world, the main strategy for controlling this disease is the use of fungicides. The International Potato Center, CIP, estimates that losses due to late blight in low-income countries cost 3.25 billion US dollars every year, of which 750 million is spent on pesticides.

Previous studies in

Potatoes in the market.

Photo: Jonathan Yuen

Central-East Africa have shown a dominance of a single lineage of *P. infestans*. This lineage is denoted US-1 and is an A1 mating type. The US-1 lineage can be identified by a mitochondrial DNA haplotype denoted Ib. However, in the late 1990's a variant of the A1 mating type was discovered in Rwanda and Ethiopia, containing a mitochondrial DNA haplotype denoted Ia. More recently, possibly the same variant was also identified in isolates from Kenya. From this point the new variant of the A1 mating type with the mitochondrial DNA haplotype Ia was designated as the KE-1 lineage. The discovery of the KE-1 lineage indicates that a new variant has been established in this region.

The biology of the pathogen has changed with the world-wide introduction of the new genotypes (a result of sexual reproduction), and more frequent fungicide applications are required to achieve a reasonable level of disease control.

Collaborators

SLU

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Daniel Shimelash Zeleke (PhD student)

Makerere University, Uganda

Geoffrey Tusiime, Anne Njoroge (MSc student)

International Potato Center (Centro Internacional de la Papa – CIP), Kenya

Greg Forbes, Elmar Schulte-Geldermann, Bruce Ochieng, Elly Auma, Abigail Ngugi

Approach

Sampling of *P. infestans* was done in Ethiopia, Kenya and Uganda. In Ethiopia, leaflets of tomato and potato that showed typical symptoms of late blight were pressed and dried. FTA cards (Whatman®) were used to archive DNA from diseased leaflets in Kenya and Uganda. Samples were taken from both potato and tomato in Uganda, but only from potato in Kenya.

A bulk DNA extraction was done with a six mm disk punched from the FTA cards (from Kenya and Uganda) and used for both mitochondrial DNA haplotyping, as well as for genotyping with microsatellite (SSR, simple sequence repeat) markers. DNA was extracted directly from the dried leaf samples from Ethiopia.

The resulting material was analysed for mitochondrial DNA haplotype, as well as determination of a genetic 'fingerprint' using the SSR markers.

Scientific results

Phytophthora infestans from 359 fields in Ethiopia, 259 fields from Kenya, and 164 fields in Uganda were analysed for mitochondrial DNA haplotype and an SSR fingerprint. These were both tomato and potato fields in Ethiopia and Uganda, but only potato fields from Kenya.

The mitochondrial DNA haplotype is the easiest way to distinguish the older, US-1 clonal lineage from newer lineages. This lineage is characterised by the Ib haplotype, and this was not found in any of the Ethiopian or Kenyan samples. These samples were predominantly Ia, although some of the Ethiopian samples showed what could have been a Ic haplotype (previously reported only from *Phytophthora andina)*, but these analyses need to be repeated. It should be pointed out that none of the Ethiopian samples from tomato were the Ib haplotype. This indicates that the US-1 clonal lineage is completely absent from both tomato

Photo: Jonathan Yuen

Potato late blight in Uganda.

and potato in Ethiopia.
The Ugandan samples were mixed, with clear differences between the eastern and western portions of the country, as well as between potato and tomato. Ugandan samples from tomato were always the Ib haplotype, irrespective of their geographical origin. Potato samples from the eastern portion of the country were the Ia haplotype, whereas samples from the western area of Uganda were Ib. In the central area, the potato samples were a mixture of Ia and Ib.

Analysis of the microsatellite data from the Ethiopian samples is still ongoing. The 359 samples were taken from 30 different fields. Genetic variation within each field was quite high, the G/N ratios (the number of genotypes divided by the number of samples) from 0.22 (nine samples) to 1 (eleven samples). A total of 170 different genotypes were found among the 30 fields. An analysis of molecular variance (AMOVA) revealed that seven percent of the variation was among the 30 populations, and only seven percent was between populations. This could hint at sexual reproduction of the pathogen, though additional evidence is clearly required.

Based on host origin and mitochondrial DNA haplotype, the Kenyan and Ugandan material was divided into three groups (Ia potato, Ib potato, Ib tomato). An SSR fingerprint made on the 426 samples yielded a total of 80 unique multilocus genotypes. Less variation was seen in the Kenyan material, however, and the 260 samples yielded only 16 genotypes (eight of which occurred only once). This can be compared to the Ugandan material, where 166 samples yielded 69 multilocus genotypes (45 of which occurred only once). If these analyses are restricted to the new (Ia) population, there is much less variation, with a total of 20 genotypes from 318 samples, five of which were shared between Uganda and Kenya. More variation was seen in the Ugandan (Ib) population, which had 60 genotypes in 108 samples. This is not unexpected, since this lineage is much older, and it appears to have specialised variants on tomato and potato. Of the 32 Ib samples from tomato, 27 genotypes were seen (23 occurred only once), and the 76 Ib potato samples had 38 genotypes (26 of which occurred only once).

A comparison of the results from the three countries revealed similarities within the Ia population. Three genotypes (A, B, and C) were common in all three countries, with slight variation between the Kenyan/Ugandan material (heterozygous 174/176 at Pi16) and the Ethiopian samples (homozygous 176/176 at Pi16 for two of the three). The different variants were different from each other at the D13 locus, with either 130/130, 132/132, or 134/134 for A, B, and C, respectively.

The US-1 clonal lineage has been displaced from potato in Ethiopia and Kenya, and a displacement is taking place in Uganda. This can only take place if the new genotypes of *P. infestans* are more aggressive than the older, US-1 clonal lineage. Based on calculations made with a simulation model of potato late blight, this means that the disease will become more difficult to control in the future, thus spurring increased use of fungicides if more resistant cultivars are not used. While the US-1 lineage has not been displaced from tomato in Uganda, this possibility still exists since newer individuals (not US-1) were found on tomato in Ethiopia. While there appears to be no immediate threat of increased fungicide use on tomato in Uganda due to a new lineage, the reasons behind the apparent specialisation of *P. infestans* on either potato or tomato raises a number of research opportunities in this region that could have wide-spread significance in a global context.

Photo: Jonathan Yuen

MSc student Anne Njoroge with a pesticide package.

"The International Potato Center estimates that losses due to late blight in developing countries cost 3.25 billion US dollars every year"

Photo: Jonathan Yuen

Diffused light seed potato storage.

Dissemination of results

Anne Njoroge's work in Kenya and Uganda was featured on a 'blog' by the International Potato Center, and will be in her MSc thesis (link to the blog: www.rtb.cgiar.org/studying-a-new-threat-to-the-potato-farmers-of-east-africa/). Work on a peerreviewed publication is in progress.

Anne Njoroge presented a poster at the African Potato Association (APA) meeting in Nairobi, Kenya, (June 30-July 4, 2013). An oral presentation was also held at the International Congress of Plant Pathology meeting in Beijing, China (August 25-30, 2013).

Gender aspects

High-value crops, such as potato and tomato, are very important for household economics among resource-poor farmers. These high value crops represent a significant source of income for many families since the cultivation of these crops often generates a higher economic return than the cultivation of other crops. Since a majority of these farmers are women, efficient cropping systems directly supports gender equality, and indirectly has socio-economic effects in terms of access to health care and schooling.

The MSc student, Anne Njoroge, has received a CIP scholarship for her work in this project and is now employed by CIP. This is a successful example of how to increase the presence of female researchers within the CGIAR system, in Africa in general, and within the national agricultural research system in Uganda.

Greatest value of the program

Through this program we have been able to show that new lineages of *Phytophthora infestans*, the causal agent of late blight in potato and tomato, are spreading in East Africa. The fact that these lineages have displaced the older, US-1 lineage is evidence that they have better fitness, and can out-compete this older lineage on potato. Simulation studies that have compared newer lineages with US-1 indicate that there will be more difficulty in controlling potato late blight in the presence of newer, more aggressive lineages. The presence of these newer lineages will not only increase the use of fungicides in potato production, but will also increase the environmental costs of using these pesticides.

A summary of the statistics for this project on p.157

High value crops and insect pest management in East Africa

Project leader: Teun Dekker

Summary in Swedish

Bekämpning av skadeinsekter på ekonomiskt viktiga grödor i östra Afrika

Många grödor fyller inte bara en viktig uppgift för näringsbehovet och behovet att säkra födotillgången, utan erbjuder också möjligheter att minska fattigdom och gynna ekonomisk tillväxt, särskilt i fattiga samhällen, genom sitt ekonomiska värde. Att stimulera produktionen av ekonomiskt viktiga grödor har en direkt gynnsam effekt på lantbrukarfamiljernas ekonomi, hälsa och möjlighet till utbildning. Det är företrädesvis kvinnorna i familjen som ansvarar för det småskaliga jordbruket. Att kvinnorna på detta sätt får inflytande över hushållsekonomin bidrar såväl till att förstärka dessa effekter som till ökad jämställdhet.
Syftet med projektet har varit att stödja och utveckla forskning, kapacitetsuppbyggnad och nätverk för vetenskaplig excellens i östra Afrika.

Två huvudsakliga studier har bedrivits inom projektet:
a) Hållbara ”push-pull”-strategier för kontroll av skadegöraren potatisstävmal (*Phtorimea opercullella*) på tomat.
b) Studier på den afrikanska invasiva fruktflugan (*Bactrocera invadens*), jordbrukares perception, lokala kontrollåtgärder, samt flugans ekologi och sinnesekologi.

Projekten har resulterat i potentiellt nya kontrollåtgärder genom samodling, nya ”push-pull”-strategier, användandet av santitetsmetoder i fruktträdgårdar, samt innovativa luktfällor. Dessa kontrollåtgärder kräver endast små insatser för att användas i praktiken. Fortsatta studier bör inriktas på att optimera kontrollåtgärderna och att identifiera möjliga hinder för att ta dessa i bruk.

Summary

Many crops not only fulfill an important role in nutritional balance and food security, but also offer potential for alleviating poverty and foster ingeconomic growth, particularly in poor communities, through their value as cash crops. Stimulating cash crops directly contributes positively to rural household economics, family health and children's schooling. The empowerment of women, who have a disproportionate share in horticulture production, reinforces these effects and also supports gender equality. This project has supported research, capacity development, and networks of scientific excellence in East Africa.

Two studies were conducted within the project:
a) Research on sustainable push-pull control of the potato tuber moth (*Phtorimaea operculella)* (PTM) in tomato crops.
b) Research on the African invasive fruit fly (AIF), *Bactrocera invadens*, focused on studying farmer perception, local control measures, as well as the fly's ecology and sensory ecology.

Both projects identified several promising avenues for intervention, including 'smart intercropping', use of repellents (push-pull of PTM), use of orchard sanitation including burying, and the use of baits, including newly developed ones in monitoring and control (African invasive fruit fly). Each of these methods requires low level input. Further research should optimize the techniques and look at barriers to implementation.

Background

High-value crops are recognized as a key factor in 'pro-poor growth' in large parts of Africa. As the fastest growing agricultural sector in Africa, high-value crops are an integral part in creating socio-economic development opportunities, in particular for smallholder farmers. Such crops improve household economics, health care and educational perspectives, particularly for women and children. Insect pests are a major threat to many high-value crops. The aim of this project was to develop long-term solutions that are economically and environmentally sustainable and adoptable for both large scale and small scale farming systems.

To ultimately propel new strategies into practice we aimed to utilize momentum created through a new sustainable pest control strategy,

UAAIE workshop demonstration of a monitoring trap for detection of the African invasive fruit fly using methyl eugenol. Several AIF flies can be seen on the trap.

Photo: Teun Dekker

called push-pull, developed by *icipe* to control the maize stem borer, *Chilo partellus*, in East Africa. Farmer awareness of the success of this agricultural production system will facilitate adoption of similar techniques for other pests, two of which were targeted in this project.

Dispersive pests such as fruit flies, however, may require additional concerted regional efforts. Large scale farming practice can be instrumental for innovation to trickle down to smallholder farming. Our research on fruit flies aims to develop innovative chemical ecological methods that can be adapted in concert with sanitation and augmentation to large-scale and small-scale farming.

Collaborators

SLU
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Addis Ababa University, Ethiopia
Emiru Seyoum, Birtukan Dessie (PhD student), MSc students: Tibebe Dejene, Tewodros Mulugeta, Bethilehem Mekonnen, Zelalem Birhanu, Mulalem Mersha – Dept. of Zoology

Holetta Agricultural Research Center, Ethiopia
Bayeh Mulatu

Arbaminch Plant Health Clinic, Ethiopia
Miriam Karlsson

Upper Awash Agro-Industry Enterprise (UAAIE), Ethiopia
Abebe Merti

International Center of Insect Physiology and Ecology (*icipe*), Kenya
Christian Borgemeister, Sunday Ekesi

Approach

The push-pull research in tomato and sugarcane in this project has taken advantage of the experience gained for control of the maize stemborer in Kenya, for which push-pull was originally developed. The technique uses a 'smart' intercropping system that pushes pest outside the cropping area, while simultaneously supporting and pulling in natural enemies and nutritional resources into the cropping system. Development of such systems involves classical chemical ecological studies, which focuses on behavioral and physiological responses of pests and natural enemy to crops, and intercrops, with and without herbivore damage. We performed our analyses in both laboratory (two-choice assays), large-field cages (multi-choice), and field plots.

Using semi-structured interviews we identified the perceived importance of the African invasive fruit fly in smallholder farming and identified locally available methods used to reduce pest levels. We also studied the minimal burying depth of infested fruit necessary for effectiveness in control. Finally, we scored the effect of sanitation on fruit fly species abundance using food bait monitoring traps.

Furthermore, we used classical chemical ecological techniques for unraveling the odors to which female and male flies are sensitive. For this, we collected individual fruit odor blends, identified the compounds within these blends to which the antennae were sensitive, and recomposed these into blends that were tested on their attractiveness for ovipositing females and sexually mature males. We analyzed the color preference of male and female flies for food and oviposition baits using sticky panels and flytraps.

Both projects involved exchange of researchers across Africa and between Africa and Europe to

Photo: Miriam Karlsson

Orchard sanitation: a burying pit with infested fruit to prevent adults from emerging. The minimal depth of these pits has been assessed in trials.

ensure technology transfer, Inclusion of participatory research facilitated adoption locally of our research findings and recommendations.

Scientific results

Our work on the potato tuber moth showed that parasitoids are not sensitive and are not attracted to volatiles that are released by tomato upon attack by PTM, which explains the lack of control using parasitoids. However, the PTM moth itself is able to sense these odors and actively avoids these. We are in the process of characterizing the odours, which may be used as a repellent to control PTM. Furthermore, we verified preference of PTM for various solanaceous plant species. Among five species tested, PTM preferred wild solanum species in both the laboratory and in the field. Tomato was not preferred in choice situations. Except for tomato and eggplant, parasitation rates in *Solanaceae*, were high, which indicates that intercropping with other *Solanaceae*, particularly wild *Solanum spp*., has the potential for use in push-pull management. Further studies will look at optimizing phenological stages and intercropping methods for use in PTM control.

Our research on the African invasive fruit fly shows that it was perceived as the second most important cause of income loss, only theft being more important. Several orchard sanitation practices were identified, among which burying seemed most promising. The minimal burying depth for effective annihilation of larvae in infested fruit was established. Furthermore, in a large-scale farm, good orchard sanitation practice in conjunction with male trapping using odour traps reduced the population of the African invasive fruit fly by over 90%. These control measures alone prevented a cut back of 55 acres of guava-plantation. However, native fruit fly species benefitted from the intervention-induced competitive release. Future research and intervention methods should thus look at how to combine control methods for several species.

Furthermore we looked in detail at the sensory and behavioral response of fly to odours extracted from fruits, as well as the colors to which flies are attracted. We identified blends of odours that attract female flies in the laboratory. After optimizing release rates and stability of the compounds, field-trials will be performed in the coming year. Furthermore, we established that color preference varied depending on odour source, such as food, oviposition, and sexual cues. These two studies are important for designing effective monitoring and intervention methods.

The projects have directly lead to interlinking research in Ethiopia, Kenya, as well as commercial partners in Ethiopia, Sweden and the USA. Trajectories for further research and implementation

Photo: Teun Dekker

Birtukan Dessie explains the use of one of the lures that attract males of various fruit fly species, but not the African invasive fruit fly.

Photo: Teun Dekker

Emiru Seyoum (Addis Ababa University) explains sanitation to workers at UAAIE in a guava orchard with 100% AIF damage.

"Good orchard sanitation practice in conjunction with male fly trapping using odour traps reduced the population of the African invasive fruit fly by over 90%"

Photo: Teun Dekker

UAAIE harvest of citrus. During the workshop we put up monitoring traps for assaying presence of AIF in citrus. We confirmed the presence of this pest that had been previoulsy not noticed, underlining the importance of proper monitoring in control.

continue through funding from the Swedish Research Council (see below).

Dissemination of results

A pan-African workshop on chemical ecology in multi-level management (SEMIO-11) was arranged within the project. Seventysix researchers from 16 nations participated, 29 of which were supported through this program.

Furthermore, the program has endeavored to disseminate research findings by supporting national networks (AIF network in Ethiopia, linking AAU, UAAIE, Arbaminch Plant Health clinic), intra-African research excellence platform development (AIF network linking Ethiopia, and Kenya) through supporting the education of six MSc students and their research exchange.

Finally, farmer workshops and participatory research at Arbaminch, and UAAIE have resulted in quick adoption of available technology in Ethiopia. We were also very pleased by the recognition of the importance of the research through two research grants (a postdoc and a PhD student in Ethiopia), which ensures continuation of the research initiated during the course of this project.

Gender aspects

Women are disproportionally engaged in high value cropping systems, both in production and marketing. Programs that support these activities therefore favor economic growth, educational opportunities and health care of women and children. In addition, our research exchange and publication strategies have favored the representation of women.

Greatest value of the program

1. Training of six MSc students, one PhD student, and one postdoc in innovative control of insect pests. Many of them will likely end up in strategic positions as important propagators of innovative, and sustainable crop protection strategies.
2. Development of an odour bait that attracts female AIF.
3. Discovery of what prevents biological control of PTM in tomato.
4. Implementation of sanitation measures in both smallholder and large-scale farming systems, and preventing a cutback of 55 acres of guava-plantation.

A summary of the statistics for this project on p.158

4. Improved efficiency of livestock production in rural areas of eastern Africa

Ear tagging of cows in Uganda.
Photo: Christina Johansson

Photo: Renée Bågge

Roadside butchery in Kampala, Uganda.

Synthesis

Livestock and animal products constitute an important contribution to food security for millions of people and will continue to do so in the future. A majority of the world´s poor live in rural areas and are highly dependent on agriculture; livestock has an important role for their income. Livestock is also of great importance for the economy of low income countries and contributes in many developing countries up to 40% of total agriculture GDP. There is, however, a big challenge to support a growing population and so far most of the increases in livestock products during the past decades have been achieved by increasing the number of animals. Further increases in numbers of livestock, particularly in Sub-Saharan Africa (SSA), are not sustainable and therefore there is a need to increase the productivity of animals instead. The gap between the potential yield productivity and the current yield is as much as 130% for beef and a staggering 430% for milk. This means there are great opportunities to enhance the efficiency of animal production by applying improvements in animal health, reproduction, breeding and nutrition.

The four sub-projects in this section have focused on; 1) quantity and quality of pasture during rainy and dry season for cattle fed on natural pasture only, 2) reproductive health management in dairy herds, 3) possibilities for genetic improvement of two livestock (cattle and sheep), 4) provide in-depth knowledge of the virus behind African swine fever (ASF).

All projects have been carried out in close collaboration with farmers and other stakeholders and this has also been a good way to carry out simultaneous extension work. It was clear from the very beginning that there are big gaps in basic knowledge in the different areas, and that much of the scientific work has been collecting base line information. Without basic information it is difficult to know in which direction the focus in research and outreach should be.

One of the indigenous cattle breeds in Ethiopia (Sheko cattle) seems to cope with trypanosomosis (sleeping sickness), and both the indigenous Red Maasai sheep and the indigenous Ankole cattle are adapted to harsh environmental conditions. In one of the projects we observed that calves with less Holstein-Friesian (HF) cross grew better compared with calves with a high level of HF. It was further obvious that one of the problems is lack of common practice among farmers to keep records over their animals and that breeding is often indiscriminate; this means there are no organized breeding programs. Capacity development and training are required for both better breeding programs and for improved productivity health. Reliable information about genotype is necessary to ascertain the most favourable level of cross-breeding required for resilience in different environments. At farm level, it is desirable that farmers start keeping breeding records so they can plan and control livestock breeding for the future.

The quantity and quality of pasture are major challenges, especially during dry season, and particularly for farmers that rely on pasture alone to feed their cattle. Results from one project reveal that the pasture in south western Uganda could be considered to be low or moderate. The cows lose weight during dry season and this in turn gives problems with reproduction. One option for the farmers could be to plan the mating more and try to produce calves during early rainy season. Artificial insemination is a possible way to improve pregnancy rate but an operational herd recording system is necessary to guarantee the quality of the insemination.

The devastating disease AFS is a big challenge for pig production and one of the projects has established a methodology to do closer studies of this viral disease. A finding of great importance was that all stakeholders in the pig production value chain spread the disease.

Ultimately, the information gathered in the four sub-projects can be used to design sustainable efficient livestock production programmes.

Ewa Wredle (coordinator)

Livestock productivity and food security in the rangeland pastoral communities in Uganda

Project leader: Ewa Wredle

Summary in Swedish

Mjölk- och köttproduktion i Uganda

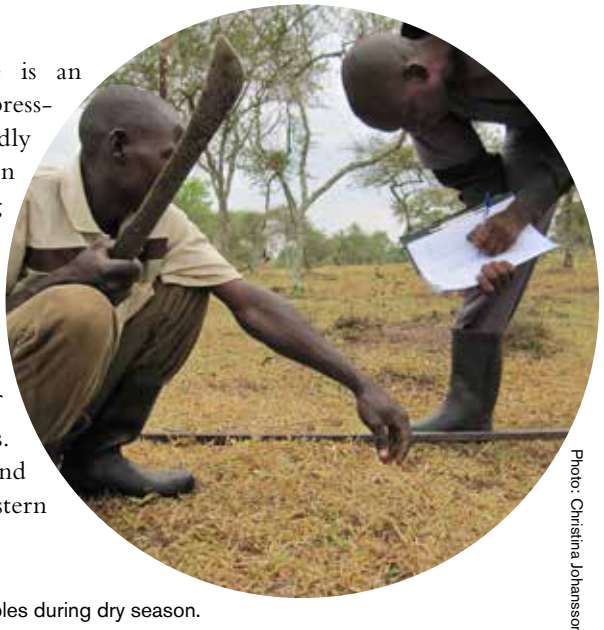
Naturliga betesmarker på torra och halvtorra områden är av stor betydelse för produktion av mjölk och kött världen över. I sydvästra Uganda, där en stor del av landets mjölkproduktion sker, har lantbrukare (bofasta pastoralister) korsat den lokala rasen Ankole med den mer högavkastande mjölkkorasen Holstein-Friesian. Vi har undersökt betesmängd och dess kvalitet under regn och torr – period, vilka skötselrutiner av djur och betesmarker lantbrukarna använder samt hur dessa faktorer påverkar produktionen. Under torrperioden fanns som väntat mindre mängd bete tillgängligt och det hade lägre innehåll av energi och protein. Högre proteinnehåll i betet, vilket fanns i tidig regnsäsong, hade en positiv inverkan på kalvarnas tillväxt. Vi observerade att kor som kalvade i slutet på regnsäsongen tappade mer i vikt än de som kalvade i tidig regnsäsong. Antal dagar i torrsäsong hade en negativ, men relativt liten, påverkan på mjölkavkastningen. Troligen använde korna sina kroppsreserver för att hålla mjölkavkastningen uppe. Vi noterade att kor som var i sin tredje laktation eller mer hade en högre mjölkavkastning (8,7 kg/dag) än yngre kor som avkastade 6,6 kg mjölk/dag. Kor som mjölkades 2 gånger per dag hade en högre avkastning (+2 kg/dag) jämfört med kor som mjölkades en gång. Att mjölka 2 gånger per dag var dock inte möjligt för många av de gårdar vi studerade då det innebär mycket arbete att hämta och mjölka korna och det är brist på arbetskraft. I den workshop vi höll för lantbrukare, rådgivare och lokal myndigheter var ett starkt önskemål från lantbrukarna är att kunna börja mjölka med hjälp av små mjölkmaskiner vilket är ett naturligt steg för en ökad mjölkproduktion.

Summary

Grasslands in arid and semi-arid lands are very important in meat and milk production worldwide. The agro-pastoralists in the rangelands of south western Uganda, an area that holds a high number of dairy farms, depend entirely on natural pastures as the main feed resource for their livestock. To increase milk yield, these pastoralists have crossed their local Ankole cattle with the exotic Holstein-Friesian breed. In the present project, we investigated quantity and quality of pasture during both the rainy and dry seasons, and how animal management routines in the agro-pastoral dairy production system are performed. There was more pasture available in the rainy season, and highest protein and energy contents were found early during this period. Calves subsequently grew better when consuming high protein fodder. Average energy and crude protein content in pasture was 7.4 MJ ME/kg dry matter herbage and 6.6 % CP which is too low for crossbred cattle to give high milk yield. Cows that calved in the end of rainy season lost more weight during the dry season compared with cows that calved in early rain season. Numbers of days in dry season had a negative, but relatively small, impact on milk yield. This is most likely because the cows were milked on their reserves, and thus lost body weight. The farmers also have a strategy to give available feed to the highest yielding cows whereas the rest of the herd must manage on what was left. Cows in their third lactation or more had a higher milk yield (8.7 kg/day) compared to first lactation cows (6.9 kg/day) and cows that were milked twice per day milked more (+2 kg/day) than cows milked only once daily. However to milk twice per day is difficult for many of the farmers since it is very time consuming to fetch and milk the cows, plus there is a general lack of labour. During a workshop held for farmers and other stakeholders a strong wish expressed by farmers was to be able to milk with machines in the future.

Background

In Uganda there is an increase in land pressure due to a rapidly growing population and a growing demand for livestock products. These, as well as other factors are changing the lifestyle of many pastoralists. In the rangeland of south-western



Collecting grass samples during dry season.

Photo: Christina Johansson

Uganda, the pastoralists have settled down and nomadic pastoralism has been transformed into an agro-pastoral system. Since settling, many agro-pastoralists have crossed their indigenous Ankole cattle with the high yielding Holstein Friesian to get crosses with a higher milk production potential. However, the nutritional and management demands are higher in these crosses. Furthermore, natural pastures, which are the main source of feed, may not supply all the needed nutrients throughout the year. The problem with feed is even more serious during the dry seasons when both quantity and quality of the pasture drop significantly. Yet another problem is that there is hardly any base line information about livestock husbandry and productivity in this region and it is thus needed to gather basic information before any recommendation can be given to the farmers. The system change from nomadic to sedentary is a major shift in production system and there is need for knowledge in order to improve the productivity of the pasture and animals. The overall aim of the present project was to investigate the seasonal changes of the pasture quality and quantity and how calf and cow husbandry are performed. We also evaluated the effect of protein supplementation on the growth of cross bred claves maintained on natural pastures. A more long term objective is that this information can be used in feeding recommendations and management guidelines.

Collaborators

SLU

Ewa Wredle, Eva Spörndly, Christina Johansson (PhD student) – Dept. of Animal Nutrition and Management

Makerere University, Kampala, Uganda

Elly Sabiiti, Denis Mpairwe, Sylvester Katuromunda, Mary Tibezinda, (PhD student, partly included in the project), Ignatius Katongole, Regina Nabisubi (MSc student) – Dept. Agricultural Production, School of Agricultural Sciences, College of Agricultural and Environmental Sciences

Approach

All practical parts have been performed in the field at farm level together with farmers on their farms. Surveys regarding animal husbandry, herd structure, and animal health etc. were conducted by two female PhD students, one from SLU and one from Makerere University. Production performance of cows (milk yield) and calves (growth) and pasture sampling has been done during both dry and rainy season. We have also done a more controlled experiment on 3 farms where growing calves have been fed with protein-rich supplements that were grown on the farms. An important aspect is that all feed needs to be analysed regarding dry matter, protein content, fibre content, energy and ash. We therefore included a laboratory course at SLU so that the technicians at the feed laboratory at Makerere will be able to analyse feed quality themselves in the future using methods that are commonly employed today worldwide.

Scientific results

The pastures in the study area were of poor to moderate quality and season (i.e. dry season) clearly affects the pasture negatively. The average available herbage mass was highest in October (two month after rain started) with about 1600 kg dry matter (DM)/ha and the lowest level was found in February-May with 600-800 kg DM/ha. Energy and protein content in the pasture ranged between 6.7-8-8 MJ metabolizable energy/kg organic matter and 5-9% respectively. Both the low quantity and low quality resulted in decreased milk yield during the dry season. Daily milk

Photo: Christina Johansson

A farmer delivering milk at the local milk collecting centre.

decreased by approximately 0.5 kg for every tenth lactation day when the cow was in her first two months in lactation, if this occurred in the dry season. The cows also lost weight if they calved in the dry season. Furthermore, cows that calved in the end of the rainy season lost more weight during the dry season compared with cows that calved in early rain season. The distribution of calving's during the study period was spread relatively evenly throughout the month, and the farmers could benefit from starting to plan mating cows to produce calves to a greater extent during early rainy season. Crossing cows with HF gave a higher milk yield averaging at around 7-9 kg per cow and day. This is actually lower than the genetic potential for these cross breeds, so there is absolutely room for improved productivity.

Calves grew better during periods when the fodder protein content was higher i.e. during early rainy season. This was also seen when the calves, from the age of 6 month+, were supplemented with protein-rich feed, since they grew better compared with calves that only grazed. In the future, a suitable forage legume could be sown into the natural pastures to improve the quality. An interesting and perhaps important finding was that calves with less cross of HF grew better compared with calf crosses of high level HF. This could be an effect of the indigenous Ankole, which can cope with less feed of high nutritional value. But it could also be due to fact that Ankole cow's milk has a higher fat content that benefits the calves.

At night some of the farmers let the cows stay on pasture, whereas others kept their cows close to the farm with no access to pasture. Cows with a possibility to graze late evenings, nights and early mornings had a higher milk yield. An interesting observation was that many of the farmers milked their cows once per day; those that milked them twice did so with few hours between each milking. Cows are hand milked which is a labour intensive operation, and there is a lack of available labour. However, cows that were milked two times per day had a higher milk yield, and have potential to give even further increases if the interval between milking's was extended. The farmers told us that, given the opportunity, they would immediately abandon hand-milking in favour of bucket machine milking. The latter would be the next logical step in increasing milk production.

Dissemination of results

Publications – Four manuscripts have been developed for publication in peer reviewed scientific journals, two of which have been submitted and two still in manuscript form to be submitted; additionally we expect one more paper from the Postdoc.

Capacity development – trained one postdoc and one PhD student at SLU and built the capacity of two research assistants working with the farmers at Kazo. One laboratory technician from Makerere spent about two months at our SLU lab being trained in sample analyses using modern equipment, and he held a training course later at the laboratory at Makerere for the technicians working there.

Workshop's and courses – One work shop including also 1 field day for farmers and extension officers were conducted to build farmers capacity in dairy cattle management and feeding.

Outreach-material – Farmers received several publications (books) and brochures on livestock management during a workshop. We will also make one pamphlet in the local language for the farmers about feeding recommendations. The results of the research were televised on TV station and broadcast on several radio stations and this has impacted on several farmers who were not included in the study, or who live nearby the study area.

Photo: Sylvester Katorumunda

John Nushabe (dairy farmer in Kiruhura, Uganda) is measuring the circumference of the cow in order to calculate its weight. Christina Johansson (PhD student) is recording the data.

"The program has supported us to work more directly with many farmers which is a very good way of increasing impact of the research"

Photo: Christina Johansson

A farmer workshop in the field.

Innovations/commercialization – Calf feeding does not have a major management aspect in the agro-pastoral communities and this project – using home-made feeds – we consider to be an important innovation in this pastoral community system. A possible commercialization of the latter will be the next step of the project.

Gender aspects

The research was conducted in pastoral/ agro pastoral communities in Kazo, Kiruhura District, Uganda where both men (60%) and women (40%) participated in the research project. The senior scientists (two women) from SLU and two male scientists from Makerere supervised a woman PhD student from SLU and a male postdoctoral fellow from Makerere University.

A good number of research colleagues attended the workshop in Kazo in Nov/Dec 2012 and the workshop was well attended by both male and females who discussed the results confidently. However, the tradition in this area is that only men can own farms and only men take care of large animals such as dairy cattle, and this includes milking. We emphasized that also women should attend the workshop and the target end users were both men and women, gender percentages as above.

Greatest value of the programme

The program has given us a fantastic opportunity to strengthen an ongoing collaboration between researchers at Makerere University and at SLU. We have a strong team for networking on research and graduate supervision, and this has deepened during this program. Of special value was the possibility for capacity building at SLU since we were also able to support a Swedish PhD student in the program. She will now continue her carreer in Uganda where she will be a project leader at a local dairy plant and develop milk production in south western Uganda. Not least the program has supported us to work more directly with many farmers which is a very good way of increasing impact of the research. The program also gave us a possibility to improve feed analytical methods at the feed laboratory at Makerere, and this is crucial for performing research of a high scientific standard.

A summary of the statistics for this project on p.159

Reproductive health management in dairy cows in Uganda

Project leader: Renée Båge

Summary in Swedish

Fruktsamhetsarbete i mjölkkobestättningar i Uganda

Fruktsamhet hos mjölkkor är en av de viktigaste faktorerna som styr mjölkproduktionen. Kon måste föda en kalv för att börja producera mjölk och hon bör sedan fortsätta att kalva med ett års intervall. Att betäcka eller inseminera kor i rätt tid efter kalvning och att få bra dräktighetsresultat har därför avgörande betydelse för mjölkböndernas ekonomi.

Vårt projekt har bestått av tre element: 1) Fältstudie med kartläggning av mjölkkornas fruktsamhet och skötselrutiner efter kalvning. 2) Intervjustudie om kunskaper, attityder och tillämpning kring användningen av artificiell insemination, AI, på mjölkgårdar för att hitta faktorer som kan förbättra fruktsamheten. 3) Fortbildning av Makerere-universitetets veterinärmedicinska, kliniska lärare och forskare i diagnostiska hjälpmedel (gynekologiskt ultraljud och laboratorieanalys av könshormonet progesteron) för att förfina metoderna för sexuell hälsokontroll i undervisning, forskning och hälsoarbete ute på gårdarna.

Trots de rådande, lågintensiva systemen för mjölkproduktion finns det potential att korta ner kalvningsintervallen och öka livstidsavkastningen om cykliska kor identifieras och blir betäckta eller inseminerade i rätt tid då de återhämtat sig efter kalvning. För att förbättra AI-servicen i Uganda och få bättre dräktighetsresultat föreslår vi fortsatt utbildning av djurägare, fortbildningskurser för AI-tekniker och främjande av mjölkkoraser som är anpassade till de rådande förhållandena. Det är även nödvändigt med en fungerande rapportering på besättningsnivå för att garantera kvaliteten på det inseminationsarbete som utförs av godkända och registrerade AI-tekniker och spermadistributörer. Högre utbildning av kliniska lärare och forskare på universitetet försäkrar att nya generationer forskare, lärare och fältrådgivare utbildas och omsätter kunskaper till praktik. Sammantaget ger de tre delstudierna underlag för rådgivning som främjar fruktsamhetsarbetet och därmed ger en effektivare produktion och tryggad livsmedelsförsörjning.

Summary

Dairy cow fertility is one of the most determinative factors for milk production. The birth of a calf is necessary for initiation of milk production, ideally followed by a new calf being born each successive year. It is therefore of utmost importance for the dairy herd's economy to mate or inseminate a cow within a certain time period after calving, and thus achieve a good pregnancy rate. Our project has consisted of three elements: 1) A baseline field study for the characterization of dairy cow fertility and management routines after calving. 2) Continued education of veterinary medicine clinical teachers and researchers at Makerere University in diagnostic tools (gynecological ultrasound and laboratory analysis of the sexual hormone progesterone) for refined monitoring of reproductive functions in teaching, research and in herd health programmes. 3) An interview-based study of knowledge, attitude and practices towards the use of artificial insemination (AI) in dairy farms for the identification of factors that can improve fertility.

We conclude that, despite the prevalence of low-input production systems prevalent in Uganda, there is potential for shortened calving intervals and higher lifetime production and profitability if cyclic cows are identified and mated at the proper time point after calving. With regard to the results of our study, and in order to improve AI services and cattle pregnancy rates in Uganda, we propose the following: a) further farmer education and sensitization, b) organisation of refresher courses for AI technicians and c) identification and promotion of cattle breeds better adapted to the prevailing conditions. In addition, an operational herd recording system is necessary to guarantee the quality of the insemination service delivery by authorized and registered AI technicians and semen vendor units. Higher education of clinical teachers and scientists at the university ensures that new generations of scientists, teachers and field advisors are educated and convey knowledge into practice. Altogether, the three subprojects form a basis for improved repro-

Swedish undergraduate veterinary student Camilla Eklundh interviews dairy farmer in Kampala, Uganda.

Photo: Sandra Björk

ductive health management in dairy herds and increased production efficiency, thereby contributing to food security.

Background

Reproduction and lactation are key parameters that determine the level of production and profitability in a dairy herd. Fertility problems lead to insidious productivity losses which can be directly translated into great economic losses, and infertility is also the major reason for involuntary culling of dairy cows. Good reproductive performance ensures high productivity in a herd, minimizing the carbon footprint of each unit of milk and meat produced. Thus, improved animal health, reproduction and longevity are means to improve peoples' livelihoods and reduce environmental impacts of production.

In Uganda, poor reproduction efficiency in dairy cows is seriously hindering farmers ability to utilize the cows' full production potential. Husbandry factors around calving and the subsequent recovery period are particularly critical for successful re-breeding of cows and for future milk production. Artificial insemination (AI) is the reproductive biotechnology that has the greatest impact on genetic progress and production in cattle, and it is the breeding tool that is most motivated to use in developing countries due to its simplicity, low cost and positive outcome. Very few, less than 10%, of the dairy cows in Uganda are bred by AI and there is skepticism among farmers towards the cost benefit of AI.

The aim of our project was to identify ways to improve reproductive performance and thereby productivity in dairy farms in Uganda.

Collaborators

SLU

Theodoros Ntallaris, Lennart Söderquist, Camilla Eklundh, Ulf Magnusson and Renée Båge – Department of Clinical Sciences

Makerere University

Benon Mbabazi Kanyima (the combined Sida-financed PhD student/senior lecturer/herd health advisor) and his colleagues and supervisors Maria-Goretti Nassuna-Musoke and David Okello Owiny – College of Veterinary Medicine, Animal Resources and Biosecurity

Several other colleagues and staff members have participated in the project's different activities.

Approach

A baseline field study of dairy cow fertility was conducted. We recorded husbandry factors affecting resumption of sexual functions after calving in two production systems: open-grazing and zero-grazing. We monitored 24 dairy herds with 59 crossbred exotic cows (Holstein Friesian cows x local breeds). We took repeated milk samples and analyzed their progesterone content to determine the onset of ovarian activity and sexual cyclicity. Body condition was scored and energy balance was evaluated by a ketone body cow-side test. A Swedish research assistant participated during six months in the field work and implemented the analysis methods in the reproduction laboratory at Makerere.

We also performed an interview-based study of knowledge, attitude and practices towards the use of artificial insemination in dairy farms for the identification of factors that can improve fertility, health and production. A Swedish undergraduate veterinary student interviewed farmers using either bull or AI, AI technicians and semen vendors in the regions of urban/peri-urban Kampala and Entebbe. A Swedish specialist from SLU visited and interacted during the field work.

In connection to the two scientific studies, capacity-developing activities took place both at Makerere in Uganda and at SLU in Sweden (see pages 58-59).

Scientific results

Field study on dairy cow fertility

Cows in the zero-grazing production system in urban/peri-urban Kampala achieved a higher ($p<0.05$) average milk yield of 16.1 liters (range 5-35) compared to the 11.7 liters (range 4-22) produced by cows reared in open-grazing production. Cows with the lowest body condition were found in the zero-grazed system where the main supplement was energy-deficient banana peelings, and where there was limited access to water. Milk production was significantly higher where beer-brew waste was singly used as a supplement in comparison to other supplement sources, e.g. banana peels, mill products (maize or wheat bran) or molasses brew-waste mixed diets.

A high proportion, more than 80 %, of the cows recovered ovarian function quickly and had their first ovulation before 56 days after calving. However, most of them failed to maintain the acti-

vity and; regular sexual cyclicity was only recorded in 24% of all cows. The rest of the cows did not resume cyclicity until much later or experienced cycle cessation or abnormal, prolonged luteal activity after their first ovulation. The interval from calving to first ovulation (range 15 to 91 days) and the different patterns of ovarian function, reflected by different progesterone profiles, could not be associated to production system, feeding regimes, supplementary feed sources or water accessibility. Calving history, as reported by farmers, revealed that assistance was frequently provided: they intervened in 21% of the parturitions. Farmers perceived that as many as 30% of the cows suffered from retained foetal membranes after calving.

Cows resumed ovarian activity surprisingly early after calving but they were apparently not in condition to pursue regular sexual cyclicity, which is a prerequisite for successful rebreeding. The reason for this may be a combination of inadequate energy and low immune status due to feed scarcity, and that their bodies favour lactation at the expense of the reproductive system. Too early, or inappropriate, intervention at calving, and, in cases of retained foetal membranes which poses a risk for damages and infections in the genital tract thereby delaying sexual cyclicity, reduces chances for a new pregnancy. With improved management around calving, the cows have potential to recover their sexual functions and be mated or inseminated earlier in order to increase production efficiency and lifetime milk production.

Interview study on the use of artificial insemination in dairy farms Uganda

The compilation of answers from interviews with farmers, AI technicians and semen vendors suggest that there is a lack of knowledge among famers on herd management, nutrition, and oestrous detection and on how to select a suitable bull for their cows. There is also a lack of knowledge among AI technicians on sperm handling, on how to perform the AI technique properly, and on how to work in hygienic way in order to avoid spreading diseases. There is a lack of reporting of AI data to a central database, and no national breeding regulation authority that registers and manages technicians and administers AI activities.

In order to mitigate reproductive failures from AI and improve AI services in Uganda, the study proposes farmer education and sensitization, refresher courses for AI technicians, identification and promotion of cattle breeds adapted for prevailing conditions, operational herd recording and authorized, registered AI technicians and semen vendor units.

Dissemination of results

Publications

One scientific paper (the fertility field study) will shortly be submitted to a scientific, peer-reviewed journal. One MSc thesis, based on the study of artificial insemination in Uganda, has been presented by a Swedish veterinary student. Three conference reports have been presented as abstracts and posters at international scientific conferences. Two popular science summaries of the project have been presented as abstracts and oral presentations at symposia in Uganda and Sweden within the SLU Africa Food Security Research Programme. All seven publications have been jointly produced by the SLU and the Makerere research groups.

Capacity building

Higher education of Makerere university staff took place in Uganda and in Sweden, in the field of bovine reproductive health management in theory and practice. Diagnostic tools for refined and precise monitoring of reproductive health were implemented, such as gynecological ultrasound and assays for hormone analysis. Colleagues in the Makerere Reproduction Group are, besides being scientists, also involved in teaching of undergraduate veterinary students and of AI technicians, and they are active themselves as herd health extension veterinarians. Through them, new knowledge and techniques will be effectively distributed in academia and in livestock production.

Photographer: Markus Abrahmsén

Course in bovine gynaecology where PhD student Benon Kanyima is training with ultrasound under supervision of Renée Båge and Theodoros Ntallaris outside Kampala, Uganda

"Good reproductive performance ensures high productivity in a herd minimizing the carbon footprint of each unit of milk and meat produced"

Photo: Theodoros Ntallaris

Waitng for a small bottle of milk in Wakiso district, Uganda

Courses

Two workshops, one in Kampala, Uganda, and one in Uppsala, Sweden, were conducted within the overall SLU Africa Food Security Research Programme. A clinical course, including theory and practice, in gynecological ultrasound and reproductive health management was run by a Swedish specialist for the academic staff in the reproduction group at Makerere. A compendium was produced with material enabling the Makerere staff to run further courses. A clinical course in embryo technologies, including theory and practice, run by Swedish specialists at SLU and at the breeding company Viking Genetics and Nötcenter Viken, was attended by the PhD student/lecturer from Makerere.

Outreach material

Besides the continuous spread of knowledge from the Makerere staff, outreach material has been planned such as a simple guide for farmers and AI technicians on how to combine suitable cows and bulls at breeding. Information to farmers about the benefits of artificial insemination will be spread via an existing, popular veterinary radio show in Gulu, Northern Uganda.

Gender aspects

Both genders have been represented among scientists, supervisors, teachers, conference participants and students in Sweden and Uganda. Both male and female farmers participated in the fertility field study and in the interview study. It was never necessary to actively influence the gender distribution.

Greatest value of the programme

The two scientific projects describe the current status of dairy cow fertility and the possibilities for artificial insemination and strategic breeding programmes. They form a basis for further research ideas, improved reproductive health management in dairy herds and increased production efficiency, thereby contributing to future food security. The capacity-developing element will have the most long-term impact: Higher education of clinical teachers and scientists at the university and implementation of diagnostic tools ensures that new generations of scientists, teachers and field advisors are educated and continue to convey knowledge into practice – both in Uganda and in Sweden.

A summary of the statistics for this project on p.160

Animal genetic resources for improved livestock productivity under harsh environmental conditions

Project leader: Erling Strandberg

Summary in Swedish

Genetiska resurser för förbättrad boskapsproduktivitet under ogynnsamma miljöbetingelser

Vi studerade hur man genom avel kan förbättra två husdjurspopulationer av vikt för livsmedelssäkerheten i östra Afrika. I första fallet undersöktes skillnader mellan olika etiopiska koraser i motståndskraft mot trypanosomiasis (sömnsjuka) i områden där tsetseflugan är smittspridare. Trypanosomiasis är en av de värsta sjukdomarna och leder bl.a. till att djuren får nedsatt produktivitet och ofta dör. Rasen Sheko från sydvästra Etiopien visade sig vara mycket motståndskraftig mot sjukdomen. Sheko finns i relativt litet antal och därför prövas olika avelsprogram för att bevara och utveckla rasen och för att sprida de bra generna till andra raser. Resultaten har publicerats i en doktorsavhandling och presenterats i en workshop för berörda intressenter i Etiopien. Projektet har genomförts i samarbete med International Livestock Research Institute (ILRI) och Ethiopian Institute of Agricultural Research.

Det andra fallet handlar om fårrasen Red Maasai (RM) i Kenya, en ras känd för sin resistens mot parasiter och förmåga att överleva även under långa torrperioder. RM har länge korsats ohämmat med den sydafrikanska rasen Dorper, som ger bättre slaktkroppar än RM. Det har lett till en kraftig minskning av RM. Dorper är dock mer sjukdomsbenägen än RM och överlever inte långa torrperioder. Masajområdena har, p.g.a. senare års långa torrperioder, drabbats av stora djurförluster. Avsikten med projektet är att få aktuella data om de båda fårrasernas och deras korsningars egenskaper, och att utveckla bra avelsstrategier som säkerställer utvecklingen av RM och samtidigt ger möjligheter till kontrollerad korsningsavel för produktion av slaktlamm. Avelsmålen har bestämts tillsammans med djurägarna, slaktkroppsstudier har genomförts och en fårkontroll i pilotskala har utvecklats tillsammans med nitton fårägare i två masajområden. Betydelsen av fårproduktionen för kvinnor har särskilt uppmärksammats liksom betydelsen av mjölkproduktion för humankonsumtion. Projektets resultat har diskuterats i tre olika workshops med djurägare, rådgivare och företrädare för olika organisationer. ILRI:s medverkan har varit en förutsättning för projektets genomförande.

Summary

Trypanosomosis is one of the most disastrous animal diseases in the tropics that hinders human inhabitation and significantly reduces livestock productivity. In the present project we explored the opportunities for genetic improvement of two livestock populations that are important for food security in Eastern Africa. Firstly, in collaboration with the International Livestock Research Institute (ILRI) and Ethiopian Institute of Agricultural Research, we compared trypanotolerance among four indigenous cattle breeds kept in tsetse infested areas of Ethiopia. The Sheko breed showed clear tolerance to trypanosomosis. Strategies are now developed for disseminating the trypanotolerant genes into a broader livestock population in the affected regions. Results have been presented in a PhD thesis and discussed with national stakeholders in a workshop in Ethiopia and have been taken onboard by the Ministry of Agriculture for translation into practice, including action research in a proposal to be considered by IFAD.

The second case focuses on Red Maasai (RM) sheep, a breed adapted to harsh conditions in East Africa. Due to indiscriminate crossbreeding with Dorper, a meatier but less hardy breed, the RM population has declined drastically. Recent recurrent severe droughts have shown the superior survival ability of RM. The project builds on a pilot recording scheme of flocks in two Maasai village areas, where data on body size, reproduction and survival have been recorded. Breeding objectives have been assessed with farmer participation. RM has shown superior adaptation to the harsh environment; although the Dorper breed had a better growth rate. The importance of sheep production for women has been specifically recognized as well as the value of milk production for human consumption. Design of appropriate breeding strategies for conservation and improvement of RM are being developed. Progress and results have been shared with farmers and stakeholders at workshops with ILRI as an important partner.

A Red Maasai Sheep ewe together with her lamb, at Kapiti Plains Research Farm, ILRI, Kenya.

Photo: Emelie Zonabend

Background

The demand for livestock products is expected to double in the coming decades. Previously, an increased demand for food of animal origin has mainly been met by an increased number of animals, rather than by increased productivity from fewer animals. In sub-Saharan Africa, ruminants play an important role by converting forage to high value protein for human consumption. Achieving this by even larger herds and flocks is neither possible nor sustainable. Increased productivity, producing more from fewer animals, is a necessity.

Indigenous livestock breeds are generally well adapted to harsh tropical environments. Some breeds are drought and disease tolerant - attributes important for adaptation to climate change. However, due to inadequate selective breeding, indigenous breeds are often unproductive. Instead, crossbreeding with exotic breeds has been practiced, mostly indiscriminately and leading to disastrous end results. Consequently, some indigenous breeds are threatened by extinction. Development of breeding strategies for specific indigenous livestock populations is therefore urgently needed in order to conserve the desired genes, improve productivity and natural resource use efficiency. This requires long-term and holistically designed efforts. However, poor infrastructure, e.g. livestock recording, and staff trained to manage animal genetic resources, remain key constraints.

Collaborators

The Department of Animal Breeding and Genetics at SLU has a long history of research and capacity building activities in the area of animal genetic resources in developing countries. Close collaboration has been maintained with the CGIAR-institute International Livestock Research Institute (ILRI), the main partner for the present studies. The Ethiopian Institute for Agricultural Research (EIAR) has been a collaborating partner in the research on trypanotolerant cattle in Ethiopia. In both cases the ministries of Agriculture in Ethiopia and of Livestock Development in Kenya have been involved. Participating scientists:

SLU

Jan Philipsson, Emelie Zonabend (PhD student), Jennie Stein, Tadele Mirkena, Birgitta Malmfors, Anna Näsholm and Erling Strandberg – Dept. of Animal Breeding and Genetics

International Livestock Research Institute, Kenya/Ethiopia

Julie Ojango, Workneh Ayalew, Woudyalew Mulato, James Audho, Tadelle Dessie, Ed Rege, Okeyo Mwai

Approach

The study on trypanotolerance of four indigenous breeds, Abigar, Gurage, Horro and Sheko, included: i) a survey in the habitat areas of each breed regarding production systems and the perceptions of the livestock keepers on trypanosomosis and other cattle diseases, ii) analysis of trypanosome infection rate using blood samples and interviews of livestock keepers about animal performance and trypanosomosis treatments, iii) study of growth, reproduction and health of the breeds kept in the same tsetse-infested environment at a field station. Live weights at different ages, body condition, fertility, survival, and indicators of trypanotolerance were recorded and analysed. Sheko was found to be most trypanotolerant. Therefore, simulation studies were conducted to find the most efficient way of conserving the breed and disseminating the trypanotolerant genes into a broader part of the livestock populations.

The study on RM included five parts conducted in cooperation with ILRI: i) a baseline survey of households, production systems and primary use and survival of sheep of various types in two Maasai village areas; ii) a pilot recording scheme was started with 19 Maasai farmers to record live weights, body size, fertility and survival of RM, Dorper and their crosses for analysis of productivity; iii) analysis of corresponding records from two research stations; iv) assessment of breeding objectives as defined by farmers and, through slaughter value studies, to advise on the directions for selection; and v) simulation studies to find optimum strategies for conservation and improvement of RM, while using a part for crossing with Dorper for production of slaughter lambs. Activities have included capacity building and outreach workshops with farmers and relevant stakeholders. A general survey has been conducted to clarify the existent infrastructure for conservation and breeding programmes in Eastern Africa.

Scientific results

In the study of trypanotolerance of four Ethiopian cattle breeds, livestock keepers in all areas where the breeds were normally kept considered trypanosomosis the most important disease. According to the livestock keepers, Sheko and Abigar had the best milk production, whereas the reproductive performance was worst for Gurage. During the peak trypanosomosis challenge period of the year, blood samples showed that Sheko cattle were least infected by trypanosomes (6%), compared to the other breeds (17-23%). Horro and Sheko had the highest (best) packed cell volume (PCV): infected animals of all breeds had lower PCV compared to non-infected animals. The number of trypanocidal treatments varied greatly, where Sheko had the fewest and Gurage the most (1 vs. 24 treatments per animal and year).

A total of 375 animals of the four breeds were kept at the field experimental station, in a tsetse-infested area (Ghibe valley). At the station Abigar and Gurage showed very poor reproductive characteristics compared to Horro and Sheko, and survival rates were best in these breeds. Sheko and Abigar had the highest PCV. Sheko had the least average number of trypanocidal treatments and the lowest infection rate, 9% compared to 21-26% in the other breeds.

The Sheko cattle stood out as the most trypanotolerant animals as they rarely got infected by trypanosomes, and had good PCV, body condition, production and reproduction. A broader use of the Sheko breed in tsetse-infested areas could improve animal health and household welfare. Continued simulation studies on alternative selection strategies will show the opportunities of conserving and further improving the Sheko breed, and disseminating the trypanotolerant genes into other cattle populations in tsetse-infested areas of Ethiopia.

In the study of Red Maasai and Dorper sheep and their crosses in Kenya, the Maasai farmers participated in assessing the values of the different breeds as well as the objectives for future selection. Farmers considered RM superior as regards drought and disease resistance as well as mothering ability, whereas Dorper was considered having higher growth rate and larger body size. Sheep milk production was found to be surprisingly valuable, probably because of the large losses of cattle during recent recurrent droughts. Further improvements of growth rate were considered important for all breed groups, whilst also considering resistance to drought and diseases. Data on live weights, conformation and carcasses have been collected to further develop the breeding objectives. Market information has clarified the opportunities for farmers to substantially increase sheep production for domestic as well as export markets. Results provide parameters needed for simulation studies to design appropriate breeding strategies for conservation and improvement of the Red Maasai as well as total flock output in relation to resource use. A possible scenario would be to have the RM sheep to constitute the main female flock and partly use it for controlled crossbreeding to produce slaughter lambs, and to continue selection for maternal and survival traits in RM. Only a limited population of the Dorper breed would be necessary to provide rams for terminal crossbreeding.

The infrastructure study revealed that very few conservation and breeding programmes are effectively put in place in Eastern Africa. Livestock recording involving farmers, as a basis for both herd or flock management and breeding, is generally not practiced. Livestock breeding policies are being developed, but are only partly implemented. The most important constraint for development of conservation and breeding programs to improve livestock production is the shortage of staff trained in animal breeding and genetics. Capacity development at all levels as well as increased training of students in animal breeding at universities are deemed necessary to improve the situation.

Dissemination of results

Results from the study of trypanotolerance of Ethiopian cattle breeds have been shared with all relevant national stakeholders at a workshop in Addis Ababa. Proposed actions have been taken onboard by the Ministry of Agriculture for translation into practice, including action research in a proposal to be considered by IFAD, International Fund for Agricultural Development. One paper and a PhD thesis were published during 2011 and one manuscript has been produced during the project period but is not yet submitted.

For the Red Maasai studies, progress and results have been shared with farmers and stakeholders

"The program has enabled us to support the farmers to improve their use of livestock and thus improve their livelihoods"

Photo: Emelie Zonabend

A woman, for whom the livestock is essential, milking one of her goats north of Amboseli, in Kenya.

at two workshops in Kenya and have led to new partnerships to upscale the activities with ILRI as an important actor in cooperation with ministries and NGOs. Two workshops of training with enumerators have also been carried out besides the continuous training with farmers and enumerators when visiting the farmers for collection of data. The paper on infrastructure has recently been published. A manuscript about the breeding objectives is currently being written. The project has been presented at various meetings and conferences. Results from both parts of our subproject were presented in Kampala for African collaborators and stakeholders as well as at the final UD40 symposium in Uppsala in June 2013.

Gender aspects

The Red Maasai project was carried out in Maasai villages in Kenya. In these villages the men are usually the owners of livestock but women that have been widowed also own sheep. Generally, however, women are the ones that take care of and know the animals best. In this project we have actively tried to involve women livestock keepers and are working especially with widows for whom livestock is essential for their livelihood.

Also in the Ethiopian project, women played an important role in livestock keeping and for food security of their families. Generally, women are in charge of the household, the children and the livestock, while men often have jobs outside the farm. Thus our project will contribute to better livelihood of rural households.

Greatest value of the program

The program has given us the opportunity to continue with valuable livestock recording within the sheep project and to support our scientific work for development of sustainable breeding strategies. It has also enabled us to support the farmers to improve their use of livestock and thus improve their livelihoods. It enabled us to complete a PhD study and disseminate the results for further translation into practice by the relevant ministry. The outreach activities and feedback to farmers would not have been possible to carry out without financing from this program.

A summary of the statistics for this project on p.161

Studies on African Swine Fever virus and its genetic variation in different host species- particularly focusing on the vector

Project leader: Mikael Berg

Summary in Swedish

Genetiska studier på afrikansk svinpest-virus med fokus på variationer mellan olika värddjur

Svinnäringen är på stark frammarsch i Uganda. Det finns flertal anledningar till detta; bland annat att grisar får stora kullar och når slaktvikt väldigt fort. Speciellt viktigt är denna näring för fattiga människor som genom att föda upp några grisar får betydligt bättre föda och ekonomi. Dock finns flertalet utmaningar och till detta rör smittsamma infektionssjukdomar såsom afrikansk svinpest. Denna virussjukdom är mycket smittsam och kan i värsta fall slå ut alla bondens grisar.

Detta projekt, som tillhör ett större internationellt projekt, avser att öka förståelsen för hur detta virus sprids mellan olika värddjur. Av särskilt stort intresse är hur vilda djur (vårtsvin, busksvin och fästingar) kan vara reservoarer för viruset för att sedan vid kontakt smitta tamgrisar, som i sin tur kan smitta andra grisar. Vi har i detta projekt speciellt introducerat så kallad "metagenomik" för att studera afrikansk svinpestvirus, men även andra virus av intresse, hos vilda djur och i tamgrisar för att utreda om smittöverföring sker i någon större utsträckning. Sammantaget fann vi nya intressanta virus båda i vilda djur och tamgrisar som i förlängningen kommer öka vår förståelse för hur dessa virus sprids och på så sätt utverka metoder för att förhindra smittspridning så att Uganda och dess fattiga befolkning kommer ha friska grisar.

Summary

The pig farming industry in Uganda is steadily increasing due to the pig's ability to give a large litter size and grow fast. This is particularly important for the poor population that can rear a few pigs for consumption or as a source of income. Several challenges can, however, hamper this positive development and one of the major constraints is infectious diseases. One of the most serious infectious diseases is the viral disease African swine fever. The virus is normally harboured in wild reservoirs but may be transmitted to domestic animals. Following the introduction of pig production poor handling of animals, meat and meat products caused enormous outbreaks with devastating consequences for the poor farmers. The aim of this project was to introduce "metagenomics" to be able to better understand the transmission routes between wild and domestic animals. The overall scope of this project was to study the viral diversity in different host species, with particular focus on the tick vector *Ornithodoros spp.*

Using metagenomics technology we found several new viruses in both wild and domestic animals that will, in the long term, increase our understanding on how viruses are maintained in wild populations and how they spread to domestic animals. This is important information enabling us to interrupt spread of diseases and, ultimately, give the poor population of Uganda healthy pigs.

Background

The overall aim of this project was to provide an in-depth knowledge of the virus behind African swine fever (ASF). The proposed project constituted one component of a larger programme (called ASFUganda) focusing on the evolution and epidemiology of African swine fever (ASF), partially funded by SLU and coordinated in Uganda by Karl Ståhl. In this project, as well as in the others, the team worked in close collaboration with the International Livestock Research Institute (ILRI) in Nairobi, Kenya, and the Ministry of Agriculture, Animal Industry and Fisheries (MAAIF) in Entebbe, Uganda.

In Uganda, pigs are a main source of protein, being

The soft tick *Ornithodoros* is the natural vector and reservoir for African swine fever virus in eastern and southern Africa.

Photo: Karl Ståhl

reared by 18.8% of agricultural households. In 2008 there were about 2.186 million pigs in the country while more recent figures indicate more than 3 million. The government of Uganda has been promoting pigs because of their large litter size and the ability to reach slaughter weight in a couple of months. The demand for pork is rapidly rising and this makes the enterprise more promising to the farmers. Pigs are now considered as one of the major livestock products that play a key role in raising household incomes, and in providing a source of protein to many families. However, pig production faces a number of constraints, one of which is infectious diseases like ASF. Variation in clinical disease from sudden death to more subtle reactions is typical for this viral disease, and it is linked to virus genome length and different genotypes. Recent molecular epidemiological studies have uncovered substantial field heterogeneity with at least 22 ASF genotypes being identified to date on the basis of C-terminus p72 gene sequencing. ASF exists in three epidemiological cycles in Africa (i) a sylvatic cycle in which ASF is naturally maintained in warthogs (*Phaecochoerus africanus)* and the *Ornithodoros* tick, and transmission to domestic pigs is through infected tick bites; (ii) a tick-pig cycle where infected *Ornithodoros* ticks transmit the virus to pigs in their dwellings; (iii) a domestic pig cycle in which ASF is horizontally transmitted between pigs only. Domestic pigs can also become infected through consumption of infected swill.

Specific objectives:

(i) Assessment of genetic variability of ASF virus isolated from different hosts and different locations.

(ii) Investigate in more detail viruses in ticks, the viral metagenomics of ticks

Collaborators

SLU

Mikael Berg, Karl Ståhl, (also guest researcher at Makerere University, Kampala, Uganda; presently at the National Veterinary Institute), Anne-Lie Blomström; Students (BSc/MSc/MFS): Matilda Brink, Lisa Lindström, Emilia Nyberg, Jenny Olsson, Emma Tejler – Department of Biomedical Sciences and Veterinary Public Health

Host department

Makerere University, Kampala, Uganda

Charles Masembe, Denis Muhangi (PhD student); MSc students: Tony Aliro, Suzan Ndyanabo, Peter Ogweng – Faculty of Science, Department of Zoology

Associated collaborators

Ministry of Agriculture, Animal Industry and Fisheries, Entebbe, Uganda, *Anna Rose Ademun Okurut*

International Livestock Research Institute (ILRI), Nairobi, Kenya

Anne Fischer, Robert Skilton, Richard P. Bishop

Uganda Wildlife Authority, Kampala, Uganda

Patrick Atimnedi

Photo Karl Ståhl

Pigs that died of African swine fever outside Kampala, Uganda.

Approach

Special focus was on soft ticks, which are known for harbouring the virus and transmitting it. Nucleic acid was prepared, parts of the genome amplified via PCR, sequenced and then analysed by various bioinformatics tools. For the "viral metagenomics" part, a similar approach as earlier using "ultra-deep" sequencing methods was done.

Scientific results

Assessment of genetic variability of ASF virus isolated from different hosts and locations

At the moment there are very few full length genomes of ASFV determined. Most genotypes are classified via the p72 gene. Initially we therefore set out to sequence one isolate fully. Then the p72 gene of several isolates was determined. Initial results of deep sequencing of the p72 gene show the absence of quasi ASF species in individual pigs and in different outbreaks. Additional analyses are on-going and will be continued.

Investigate in more detail viruses in ticks i.e. the viral metagenomic of ticks

In addition to ticks, we investigated the metagenomes of bush pigs and domestic pigs in order to assess the viral flora in all those species that may come in contact with each other and "share" viruses, including ASFV. The general conclusion from all these studies (see list of publications) was that all species have common viruses e.g. various types of small DNA viruses (TTV, PCV, PPV), which indicates that at one point the viruses were transmitted via all these species. However, they were not genetically identical, showing that the viruses have circulated for quite some time in each species after the transmission from one species to the other, without "jumping back". We were, however, unable to find ASFV using this approach in wild species and could therefore not do genetic comparisons as initially planned. Domestic pigs, on the other hand, were found to harbour ASFV as well as many other viruses. For example we found that pigs could harbour a virus called Ndumu virus. Distantly related viruses of the same family (*Togaviridae*) are known human pathogens. This virus was previously only loosely linked to human infection but with no obvious disease, and was only previously found in mosquitoes. At the time of this report analyses of the ASFV isolates from these pigs is on-going (see above).

In conclusion, we have established up-to-date methodology to be able to do a more in-depth study of this devastating viral disease. Furthermore, we have found several new variants of viruses in both wild and domestic animal species that may throw light on the viral transmission patterns between wild and domestic species.

Photo: Karl Ståhl

Sampling of pigs in the Gulu-district of Uganda. District veterinarian Tonny Aliro leads the work.

"The program has added financial support to a very important question concerning pig farming as a way for a better life for poor people"

Photo: Charles Masembe

Karl Ståhl and Edvard Okoth from ILRI release a bush pig (*Potamochoerus larvatus*) after sampling and addition of a radio transmitter. The purpose of the study was to gain better knowledge about the importance of the epidemiology of the bush pig as a wild reservoir of African swine fever.

Dissemination of results

We have published most of the data in open access journals and are currently finishing analysis of data and writing more scientific papers. We have also had three BSc theses from SLU and a number of MSc in veterinary medicine in the form of Minor Field Studies (MFS) published within this program. In addition, two Ugandan MSc's have been published. As general information on the different aspects of ASFV transmission the project leaders have informed the field veterinarians, farmers and other stakeholders of the most suitable practices for limiting the spread of this disease. This has also attracted the attention of the Uganda news media, and Dr Masembe has informed about the on-going projects on ASFV.

Gender aspects

Women are the family members that usually take care of the pigs. The outcome from this project is therefore especially important for the female family supporters. The active researchers, students and other involved in the project are a mix of both females and males so that they can all benefit from the scientific techniques and the results.

Greatest value of the program

It has added financial support to a very important question concerning pig farming as a way for a better life for poor people and one of its major constraints: the infectious disease African swine fever. It has allowed us to pursue one line of research that may not have been done at all and has given SLU students possibilities to go to Uganda and study viral diseases in real-life field situations, and the impact they have on pig and human health in general.

A summary of the statistics for this project on p.162

5. Diversified and sustainable agro-ecosystems – efficient management of resources and soil fertility

In the village of Beseku, in the district of Arsi Negele, Ethiopia.

Photo: Erik Karltun

Synthesis

This project encompasses four sub-projects which are relatively different in their scientific approach, but are inter-linked since they address important questions related to the transition from unsustainable to sustainable natural resource management in East African agriculture. The impact of this project is assessed from four different angles; scientific impact, impact on our partners, impact on the end-users and the impact on SLU. The scientific outcomes of the projects are presented in the sub-project reports but the research can broadly be divided into two major research questions:

Photo: Livingstone Chibole

Swedish scientists that participated in the Integrated Soil Fertility Management in Africa conference.

1. How does integration of different components (trees, crops and animals) affect the productivity, soil fertility and water availability?

2. Can we find ways of removing bottlenecks (theft, weeds, declining soil fertility) that prevent farmers from increasing production?

One reason for a north European university to engage in development oriented research is to contribute to capacity building of our partners. The major constraint for many of our partners is the ability to cover expenses for field work, sample analysis and other data collection. Without these resources it is not possible to do good research. One of our major contributions has gone to this kind of support and five PhD students, sixteen MSc students and ten BSc students have benefitted from this support. We have also engaged as supervisors and thus contributed to building academic capacity.

One important aspect of capacity development is to provide opportunities for researchers and students to come together and present and discuss research. We therefore sponsored the international conference "Integrated soil fertility management – from microbes to markets" (ISFM Africa; www.isfmafrica2012.org) that was held in Nairobi 22-26 October 2012, and which attracted about 300 participants. The conference was a joint venture between many national, regional and international organizations/ventures [African Association for Biological Nitrogen Fixation (AABNF), African Network for Biological Management for Soil Biology and Fertility (AfNet), African Network on Mycorrhiza (AFRINOM), International Center for Tropical Agriculture (CIAT), Stimulation and Growth of Commercial Products (COMPRO), Research Institute of Organic Agriculture (FiBL), International Institute of Tropical Agriculture (IITA), Nitrogen to Africa (N2Africa) and United States International University in Nairobi (USiU)]. Kristina Röing de Nowina was part of the organizing committee and each of the four sub-projects contributed with financial support.

Part of this support was used to cover conference fees for African students presenting at the conference.

We have organized six different end-user oriented activities. These activities made it possible to give something back to the communities where we do our research and offer not only a chance to present our findings but it is also an excellent opportunity to get immediate feedback from farmers and other stakeholders. However, as a university we do not have the capacity or the mandate to do this at a scale that would reach a large proportion of the farmers. Therefore, close interactions with NGOs, government authorities and farmer organizations is valuable to increase the impact of our research. A good example of this is the collaboration between one of the sub-projects and Vi-Agroforestry. Finally, if we consider the impact of the project on SLU we have contributed to capacity devlopment both for the academy and for the Swedish society as a whole. Many of our students have a great interest in global development problems and are looking for careers both nationally and internationally in this area. We need to respond to this interest by providing opportunities to study and do research. Finally, Africa is undergoing a rapid transformation with rapid economic growth. If Sweden envisages being an actor in these markets we need to understand both the problems and the prospects in African agriculture.

Erik Karltun (coordinator)

Soil and water management in agricultural production – participatory management of natural resources for intensified production

Project leader: Erik Karltun

Summary in Swedish

Förbättrad mark- och vattenhushållning i ett intensifierat småskaligt jordbruk – ett samarbete mellan forskare och bönder

En uthållig jordbruksproduktion kräver kunskap om hur man bäst ska hushålla med mark- och vattenresurser för att uppnå god markbördighet och effektivt vattenutnyttjande. Men den kunskapen är i sig otillräcklig för att kunna åtgärda problem med minskad markbördighet, erosion och begränsad vattentillgång. Vi måste också förstå brukaren – i Etiopien i de flesta fall en småbonde – och de komplexa faktorer som avgör hans eller hennes möjligheter att tillämpa en uthållig mark- och vattenhushållning.

I detta projekt, som syftar till att angripa mark- och vattenhushållningsproblem i Etiopien, har vi tillämpat så kallad deltagande forskning som bygger på att bönderna engageras i forskningsprocessen. Vi har använt olika intervjumetoder kombinerade med gårdsbaserade jordbruksförsök och hydrologiska studier. Några av de viktigaste slutsatserna från forskningsresultaten är att:

- Tillförsel av begränsade mängder kompost gör att grödans utnyttjande av handelsgödsel blir mer effektiv, markens mikronäringsämnesförråd ökas och vatteninfiltrationen förbättras;
- Traditionella sociala organisationer kan spela en viktig roll vid introduktion av och kunskapsspridning kring nya jordbruksmetoder;
- Kvinnliga jordbrukares möjligheter att anpassa små jordbruk till ett förändrat klimat är starkt korrelerade till deras egendomsrättigheter, möjligheter att vara representerade i olika organisationer och tillgång till information.

Projektet har varit ett samarbete mellan SLU (Institutionen för mark och miljö, Institutionen för vatten och miljö samt Institutionen för stad och land) och Wondo Genet College of Forestry and Natural Resources vid Hawassa University, Ethiopian Water Resource Institute vid Addis Ababa University.

Summary

Sustainable agricultural production needs to be based on knowledge of how soil and water should be managed in order to maintain soil fertility and efficient water use. However, this knowledge in itself is not sufficient. In order to understand problems related to unsustainable land and water management we also need to understand the manager – in Ethiopia usually a smallholder farmer – and the complex factors that determine his/her possibilities to adopt good management practises.

In this project we have in different studies practiced participatory methods, i.e. involvement of farmers in the research process, to address soil and water management problems. This has been achieved through different interview methods combined with agronomic on-farm experiments and hydrological measurements.

Based on the most important results we can conclude:

1) With only moderate amounts of compost addition, nutrient use efficiency from added fertilizer can be significantly increased, soil micronutrient status enhanced and water infiltration improved;

2) Traditional institutions can play an important role in the introduction and dissemination of new agricultural methods;

3) Female farmers' ability to adapt their agriculture to climate change is strongly correlated to their property rights, representation and participation in various institutions, and their access to basic information.

The project has been a collaborative effort between SLU (Department of Soil and Environment, Department of Water and Environment and Department of Urban and Rural Development) and the Wondo Genet College of Forestry and Natural Resources at Hawassa University, the Ethiopian Water Resource Institute at Addis Ababa University.

Background

Unsustainable use of soil and water resources is a global concern since it is jeopardizing the ambitions to achieve global food security. Furthermore, the problem is also intimately linked to climate change since about 25% of the global greenhouse gas emissions

Testing the effect of compost and fertilizer on maize in a controlled lysimeter experiment.

Photo: Workneh Bedada

originate from land-use management.

In contemporary natural resource management research, attention is not only paid to the understanding and design of improved management methods, but it also recognizes the fact that unsustainable use of soil and water resources is intimately linked to human activities and poverty. While the actual processes that lead to degradation of soil and water can be explained by natural science research, poverty cannot. Thus, inter-disciplinary approaches that include socio-economic aspects need to be used. Further, the research has to be participatory. By involving local stakeholders (e.g. farmers, local authorities, market actors) in the research process the relevance of the research and the chance of adoption of research based interventions increase.

This project has allowed us to expand research aimed at sustainable use of soil and water resources in two different areas in Ethiopia; the Blue-Nile river basin and the southern part of the Ethiopian highlands.

The overall aims of our research were:

1) to understand and identify factors that prevent farmers from managing their soil and water resources sustainably;

2) together with the farmers test management options that are affordable and locally acceptable.

Collaborators

SLU

Erik Karltun (project leader), Sigrun Dahlin, Workneh Bedada (PhD student), Anatoli Poultouchidou (MSc student) – Dept. of Soil and Environment

Kevin Bishop – Dept. of Aquatic Sciences and Assessment)

Linley Chiwona-Karltun, Tesfanesh Gichamo (MSc student) – Dept. of Urban and Rural Development

Wondo Genet College of Forestry and Natural Resources (WGCF-NR), Hawassa University, Ethiopia

Fantaw Yimer, Tizazu Abebe (MSc student) and Aklilu Bajigo (MSc student)

Addis Ababa University, Dept. of Geography and Environmental Studies, Ethiopia

Woldeamlak Bewket, Daniel Ayalew Mengistu (PhD student), Atome Abebe (MSc student)

Ethiopian Institute for Water Resources (EIWR), and Addis Ababa University, Ethiopia

Tena Alamirew (Head of the institute)

Solomon Gebreyohannis (Post-doc)

Approach

The project encompasses a broad variety of studies, and therefore a range of different methods has been used. Below follows a short description of the set-up of each study.

a) Studies on the relationship between deforestation and water flow were conducted by Solomon Gebreyohannis (EIWR) in collaboration with the Dept. of Aquatic Sciences and Assessment, SLU. Here, time series analysis of rainfall and water flow data were used in combination with land-use studies and farmers interviews to assess the roles of trees for water availability. Dr. Gebreyohannis worked as a post-doc at EIWR as part of the project.

b) Studies on the re-adoption of faba bean cultivation after it had been abandoned due to problems with thefts of beans. MSc student Tesfanesh Gichamo used interview methods such as questionnaire interviews, in-depth interviews with key-informants and focus group discussions. Content analysis was used to analyse the qualitative data.

c) Studies on women perceptions of changes in long-term temperature and precipitation, their vulnerability and causes of vulnerability, various adaptation measures, barriers to adaptation, and determinants of adaptation options were conducted by MSc student Atome Abebe, using the same methods as in sub-project b above.

d) Three on-farm experiments were conducted by PhD student Workneh Bedada and Fantaw Yimer to study the effects of combining compost and fertilizer on soil quality, N mineralization and water infiltration rate. A lysimeter facility was constructed at Wondo Genet for experiments in which ^{15}N labelled fertilizer was used to study the interaction between fertilizer and compost. This facility can monitor soil solution composition at two depths under the growing season. Dr. Yimer spent one month at SLU in Sweden to learn more about methods for measuring aggregate stability.

e) Studies on the effect of tree plantations on soil quality and farmers livelihoods in Lepis were conducted by MSc student Anatoli Poultouchidou, She repeated a ten year old study on soil carbon content by different land-uses, allowing studies on effects of land-use over time. She also compared how farmers' livelihoods and food security were affected by vicinity to tree plantations.

Scientific results

a) The studies of forest cover change on water availability in the Blue Nile River Basin of Ethiopia showed that there is no clear relationship between forest cover change and flow regime in the temporal dimension. These results may be explained by the different scale of watersheds, uncertainty about the measurement of flow extremes, and the impact of variability in rainfall within the region.

b) The re-introduction of faba bean cultivation resulted in an area being cultivated that was larger than what had been estimated, based on the amount of seeds distributed and the recommended seed rate. The decision by a household to re-adopt bean cultivation was positively influenced by previous experience in cultivating the crop and by contact with extension services. The reason for non-adoption in some villages was the spatial separation of the homestead from farmland due to villagization (local resettlement), and consequently the poor possibilities to guard the fields against thefts. Another important reason not to cultivate beans was fear of conflict as a result of reporting theft.

c) The results show that most of the women participating in this study perceive changes in temperature and rainfall, and that there is no divergence between the women's perception and the climatic data records. Women's right to land and other property ownership, their representation and participation in socioeconomic activities, and the level of participation in decision making determines both their access to basic information and their ability to adapt to climate change.

d) Important findings from the on-farm combined fertilizer and compost experiments show that with only moderate amounts of compost addition, nutrient use efficiency from added fertilizer can be significantly increased, soil micronutrient status enhanced and water infiltration improved.

e) The impact of tree plantations on farmers' livelihoods in Lepis was stronger in households situated closer to the plantations than for households located further away. Farmers who lived near the plantations had easier access to firewood and to grazing areas for their livestock. They also had more job opportunities and access to shelter, and were inspired to start on-farm *Eucalyptus* plantation. At the same time, they also had to face problems associated with the plantations such as loss of agricultural land due to the establishment of plantations, crop destruction by wildlife, and conflicts with the forest guards. In the comparison between land-uses on soil carbon it was found that over the last ten years the forest plantations had accumulated soil carbon while there had been little change in soil carbon on agricultural land.

Dissemination of results

Publications

The results from the project have been communicated in various ways. The project has contributed to the publication of four scientific articles and one book chapter. Five MSc theses have been published based on data collected within the project.

Capacity development

An important part of capacity development is the collaboration itself. By doing research together we build capacity in several aspects; academic, human, technical and institutional. Specifically, we have supported five MSc and two PhD students by funding all of (MSc students) or parts of (PhD students) their field work. We have also upgraded and repaired laboratory facilities at WGCF-NR, where we have installed a lysimeter facility with a high resolution weather station. We have also funded two guest-research visits and one post-doc position.

Scientific conferences and workshops

We have organized two scientific workshops *Water as the mirror of landscapes: How useful a hypothesis for resource management?*, Uppsala 28-29 March, 2012, with 13 invited speakers, and *Agriculture in the face of climate change,* Debre Zeit, Ethiopia, 8-9 November 2012, with 17 invited speakers), sponsored and contributed with three posters to the ISFM Africa conference (see p. 69), and held one stakeholder workshop with field training (see below).

Outreach

The project organized a stakeholder workshop, "Making soil fertility last in the highlands of Ethiopia, the case of Arsi Negelle", combined with field training for farmers workshop in Shashemene, Ethiopia on 19-20 August 2011.

The project has printed and distributed two different advisory posters for soil fertility management and compost making translated to the local language oromiffa.

"With only moderate amounts of compost addition, nutrient use efficiency from added fertilizer can be significantly increased, soil micronutrient status enhanced and water infiltration improved."

Photo: Workneh Bedada

Soil sampling in Lepis, Ethiopia. From left: a local field assistant, MSc students Aklilu Bajigo and Anatoli Poultouchidou.

Gender aspects

Gender aspects have been given attention in choice of scientific topics and project members. Four of the five MSc theses have clearly covered gender aspects in their studies, with one of the studies having gender aspects of vulnerability to climate change as the main topic. We have also tried to look at gender aspects when selecting students for MSc work. Of the five supported MSc theses three were conducted by female students. Due to the absence of on-going female PhD students in the subject area among the collaborating institutions, both PhD students that received support for their field work are male. Among the scientific workshop participants the proportion of women presenting papers was low, around 20% in both cases, despite the fact that a conscious effort to invite female speakers was made. However, the male dominance in our collaborating institutions is high and the number of potential female speakers within the subject area is therefore low. In the end-user workshop women farmers were specially invited and transportation arranged to facilitate participation.

Greatest value of the program

From an SLU perspective the project has been valuable in a number of ways. It has allowed us to deepen the collaboration with our Ethiopian partners. During the course of the project we have found time to plan for future work, and a number of research proposals have been drafted, some of which have been submitted as research applications to different funding agencies. Through the workshops we have also been able to broaden our networks and get into contact with other universities and institutions engaged in research in Ethiopia. For the Ethiopian partners the collaboration has meant that the quality of the research has been improved since resources for fieldwork, data collection and laboratory analysis have been made available. They have also benefitted from guest research visits to learn new methods, to meet Swedish researchers in different disciplines and to have access to library facilities. The most important aspect is however the collaboration itself and the academic discussion it generates. By doing research together we develop capacity – both in Ethiopian universities and at SLU.

A summary of the statistics for this project on p.163

Evaluation of Integrated Soil Fertility Management approaches for improved productivity, sustainability, and livelihoods of smallholder farmers in Kenya and Uganda

Project leader: Kristina Röing de Nowina

Summary in Swedish

Utvärdering av "Integrated Soil Fertility Management"-metoder för förbättrad produktivitet, hållbarhet och levnadförhållanden hos småbrukare i Kenya and Uganda

En uthållig jordbruksproduktion kräver kunskap om hur man bäst ska hushålla med mark- och växtresurser för att uppnå god markbördighet och produktion av grödor. I västra Kenya är det parasitiska ogräset *Striga hermonthica* (här kallat striga) ett stort problem vid odling av majs – den viktigaste stapelgrödan i regionen. Angrepp av striga leder till låga skördar vilket i sin tur leder till minskad tillgång på mat.

Tidigare undersökningar har påvisat förekomst av striga i jordar med låg bördighet, men fortsatta studier var nödvändiga för att förstå hur användningen av förbättrade majssorter med tolerans mot striga, i kombination med mineralgödselmedel, påverkar förekomst och fröbank av striga samt majsskörd. Det har även observerats att vissa sorter av sojaböna, liksom ärtväxter i släktet *Desmodium*, kan påverka groningen av strigafrön.

I detta projekt har vi kartlagt småbrukares kunskap om och strategi för att hantera strigaproblematiken. Vi har också studerat olika metoder som använts för att reducera förekomsten och minska den negativa effekten av striga i småskalig odling, samt undersökt hur olika sorter av sojaböna påverkar striga. Vi har använt olika intervjumetoder i kombination med gårdsbaserade försök i Bondo-, Busia-, Kisumu-, Siaya-, Teso- och Vihiga-distrikten i västra Kenya.

Vi har även studerat effekten på skörd när man i fältförsök använder biokol som ett jordförbättringsmedel. De viktigaste forskningsresultaten visar att:

- Småbrukarna är medvetna om problemen med striga och får information främst genom bymöten;
- De flesta odlare använder ingen metod för att bekämpa striga;
- Småbrukare skulle kunna reducera förekomst av striga genom att kombinera odling av strigatoleranta majssorter med tillförsel av mineralgödselmedel;
- Vissa sorter av sojaböna kan effektivt användas för att reducera förekomsten av striga.
- Biokol kan öka skördarna när det används som ett jordförbättringsmedel.

Fortsatta studier är nödvändiga för att se de praktiska implikationerna av resultaten ovan. Till exempel är tillgången på arbetskraft ett problem inom jordbrukssektorn i Afrika, och alla teknologier bör utvärderas också med avseende på hur de påverkar behovet av arbetskraft och gender-dimensioner.

Projektet har varit ett samarbete mellan Institutionen för mark och miljö vid SLU, the International Institute of Tropical Agriculture (IITA), Moi University och Nairobi University, Kenya.

Summary

Sustainable agricultural production needs to be based on knowledge of how soil and crops should be managed in order to maintain soil fertility and crop productivity. In Western Kenya, the parasitic weed *Striga hermonthica* (herein after referred to as striga) is a major problem in the cultivation of maize, leading to low production of the staple crop maize so necessary for food security in the region.

As previous studies have demonstrated that striga is generally found in soils of low fertility, further investigation was needed to understand how use of improved maize varieties, in combination with fertilizer application, would effect striga germination, seed bank dynamics and maize productivity. In addition, it has been suggested that certain soybean varieties have similar properties to legumes in the genus *Desmodium*, which, when used in intercropping systems, causes suicidal germination of the striga seeds, thus reducing the striga menace.

In this project we have made a survey of smallholders' knowledge of, and strategy for, dealing with striga problems. We have also conducted different studies to assess possible measures aimed at reducing the effect of striga in smallholder's fields. The above has been achieved through different interview methods in combination with agronomic on-farm experiments in Bondo, Busia, Kisumu, Siaya, Teso and Vihiga districts in Western Kenya.

In addition, in long-term trials we have assessed the

Striga spp (purple flowers) are parasitic weeds. Each plant can produce up to 500 000 seeds which remain viable in soil for many years. Striga is very common in East Africa causing yield losses of between 60-85%.

Photo: Samuel Gudu

impact of biochar as a soil amendment on crop yields.
The key findings show that:
1) Farmers are aware of the problems with striga and receive information mainly from village meetings,
2) Most farmers do not practice any striga control measures,
3) Farmers can reduce striga density and increase maize grain yield by combining IR maize with inorganic N-fertilizer,
4) Some soyabean varieties can be effective in combating striga,
5) Biochar as a soil amendment can increase soil fertility and crop yields.

Further studies are needed to assess the practical implications of above mentioned results. For example availability of labour is a major restriction in agriculture in Africa and any technologies will have to be assessed against changes to labour requirements as well as gender dimensions.

This project has been a collaborative endeavour between the Department of Soil and Environment at SLU and the International Institute of Tropical Agriculture (IITA), Moi University and Nairobi University, Kenya.

Background

Most farms in Kenya are subsistence farms of less than 1 ha, and mainly grow maize and beans as staple crops for food production. Soil fertility is declining in general, as is crop productivity, and technologies and systems that enhance resource use efficiency are needed.

This project has focused on how Integrated Soil Fertility Management (ISFM) components can improve rural livelihoods in Kenya and Uganda. We know that soybean improves soil fertility and farmer livelihoods through its nitrogen fixation capacity, organic inputs, nutritional benefits, and marketing potential. Soybean can also reduce the striga weed seed bank through suicidal striga germination. Improving soil carbon stocks through organic matter management enhances soil fertility and crop productivity. Options for soil fertility amendment can include organic resources of varying biochemical quality and biochar, where carbon is added to the soil in a more stable form.

Collaborators

SLU
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Madeleine Casselbrant, Tina Jönsson, Anna Lenksjö, Siri Lindqvist, Henrik Nordzell, Mika Rådman (all BSc students) – Dept. of Economics

The Tropical Soil Biology and Fertility Institute of the International Center for Tropical Agriculture (TSBF-CIAT) / The International Institute of Tropical Agriculture (IITA)
Bernard Vanlauwe, Livingstone Chibole

Moi University, Kenya
Robert Okalebo, Wilson Ngetich, Geoffrey Kimutai (MSc student), Patrick Obasanjo (MSc student)

Nairobi University, Kenya
Godfrey Nambafu (MSc student)

Approach

To assess various aspects of improving soil fertility in Kenyan smallholder farming systems this project has used a combination of agronomic (field trials) and socio-economic methods (household interviews, key informant interviews, Knowledge, Attitude and Practices-study). Below follows a short description of the set-up of each study.
a) To assess the use of biochar as a soil amendment four field trials were continued in Western and Central Kenya; the trials were initiated in 2006

Integrated Soil Fertility Management

Integrated Soil Fertility Management is defined as 'A set of soil fertility management practices that necessarily include the use of fertilizer, organic inputs, and improved germplasm combined with the knowledge on how to adapt these practices to local conditions. It aims at maximizing agronomic use efficiency of the applied nutrients and improving crop productivity'.

All inputs need to be managed following sound agronomic principles.

and funds within this program were used to maintain these trials, as it is becoming increasingly important to see longer term effects. Trial design consisted of three main treatments (bare fallow, crop, and crop with fertilizer) with two sub-treatments (with and without application of charcoal). Net plot size was 4x6 meters. A crop rotation of maize and soya beans was used. Mavuno fertilizer (10:26:10 NPK enriched with Ca, Mg, and S) was applied to the maize (fertilized treatments) at planting and at 6 weeks after planting (WAP) at a rate of 50-60 kg N/ha by manual broadcasting. No fertilizer was applied to the soya beans.

b) To assess farm management systems in relation to striga problems and soil fertility more than 240 farmers were interviewed in six districts of Western Kenya (Bondo, Busia, Kisumu, Siaya, Teso, Vihiga). These studies were conducted by MSc students with joint supervision of participating scientists.

c) To test the effect of combining cultivation of IR maize (WS303 – a striga tolerant variety), with the use of inorganic N as a fertilizer on reducing striga infestation, striga seed bank, improving soil fertility and increasing maize yields, field experiments [a split-split trial arranged in a randomized complete block design (RCBD) replicated more than 30 times (farms were replicates)] were conducted during the short rainy season, 2011, the long rainy season, 2012 and the short rainy season of 2012. These studies were conducted by MSc students with joint supervision of participating scientists.

d) To investigate aspects related to demand for, perception of and willingness to pay for improved seeds and fertilizers, more than 100 farmers were interviewed in Central and Western Kenya. These studies were conducted by BSc students with joint supervision of participating scientists.

e) A study of different soya bean varieties was undertaken in three districts, where four varieties were tested. Field experiments [a split-split trial arranged in a randomized complete block design (RCBD) replicated more than 20 times (farms were replicates)] were conducted during the long rainy season 2012 and the short rainy season of 2012. These studies were conducted by MSc students with joint supervision of participating scientists.

To achieve the above, scientific exchange visits by scientists from SLU and CIAT-TSBF/IITA have taken place. Students from SLU and Kenyan universities have conducted their BSc (eight students) and MSc (four students) thesis work with joint supervision by SLU and CIAT-TSBF/IITA scientists.

Scientific results

a) The current study shows that biochar has an impact on crop yield, even ten seasons after application of the biochar. However, the practical implications of this need to be assessed, i.e. availability of feedstock's for biochar production, production methods, energy and nutrient use efficiency of resources, and labour and gender aspects.

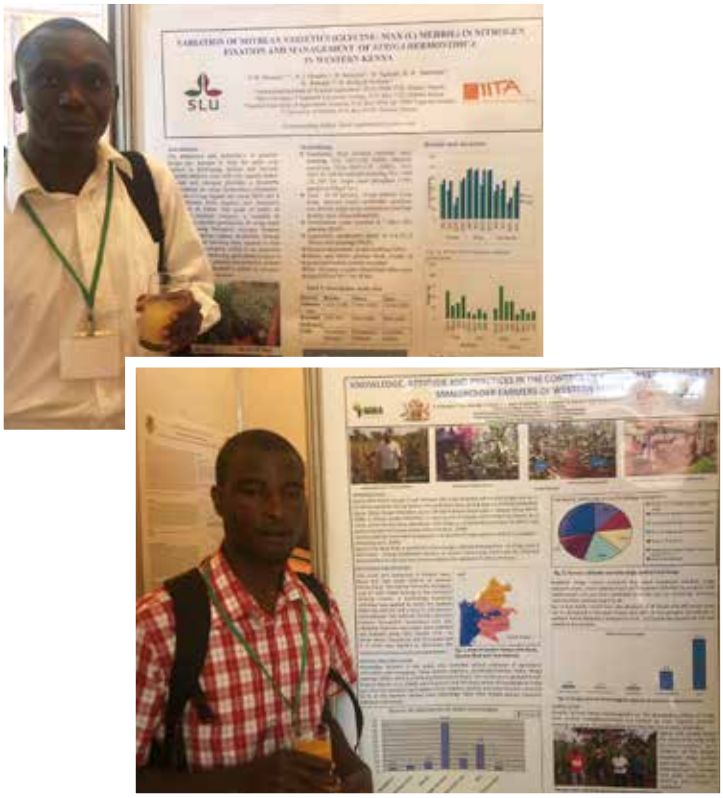
b) Farmers are aware of the problems with striga and receive information mainly from village meetings (>45% of the study group) and other informal sources (personal observations; from relatives, parents and other farmers). Formal sources such as research, extension and media only accounted for 10 % of the farmer's knowledge sources. However, most farmers (67%) did not practice any striga control measures, and about 25% practiced traditional methods of uprooting and burning and less than 10% practiced improved striga reducing technologies (push-pull, intercropping, striga resistant varieties).

c) Striga emergence differed between districts but was in general higher in the control (hybrid maize) than in the IR maize variety. Maize yields varied between 400 kg per ha and 3 000 kg per ha. IR-maize yields were significantly higher than the control across districts, although not surprisingly N-fertilizer application increased yields in all fields. Some problems with germination of IR maize were noted.

IR-maize, in combination with inorganic N-fertilizer, did reduce striga density and increased maize grain yield.

However, the practical implications of this research needs to be assessed, i.e. availability and affordability of inputs (seeds and fertilizer), as well

"The greatest value of the programme has been the capacity development opportunities for both Kenyan and Swedish students"



MSc students Patrick Obasanjo (top) and Godfrey Nambafu in front of their posters.

as use efficiency of resources, and labour and gender implications.

d) Factors that influenced the smallholder farmers' choice of methods to improve soil fertility were cost and accessibility of inputs, in combination with the farmers' socio-economic situation. In the areas where cash crops were grown, farmers were positive towards using inorganic fertilizers and improved seeds, but preferred cheaper methods. In areas where subsistence farming dominated there was hesitation towards using inputs.

The farmers' willingness to pay for inorganic fertilizer and improved seeds was less than the present market price in 2012, meaning that the market price was too high for the farmers to buy as much as they needed.

e) Soybean varieties exhibited different effects on yields. Results are still being analysed.

Dissemination of results

Four students completed MSc theses [three Kenyan (Moi University, Nairobi University) and one Swedish (SLU)]. Two BSc theses have been completed by four Swedish students (SLU). The remaining four BSc students (SLU) are expected to complete their theses by 2013.

The results have been presented as five posters at three international scientific conferences. One of these conferences (ISFM Africa; see p. 69) was sponsored by the project.

The results will furthermore be disseminated by publication in peer-reviewed papers.

Capacity devlopment has taken place through joint SLU and CIAT-TSBF/IITA supervision of the BSc and MSc students.

A stakeholder workshop and training for agricultural suppliers "Empowerment of poor farmers through legume-base Integrated Soil Fertility Management in the Lake Victoria Basin in Africa (Kenya and Tanzania) – Agri-input dealer training" was conducted in Maseno, Western Kenya, with more than 40 participants in November 2011.

Gender aspects

Gender aspects have been taken into account in several ways. Firstly, the project leader is a woman. Secondly, six out of the ten students were female. In addition, gender disaggregated data was collected, where relevant. Gender aspects were also taken into account when deciding on speakers and sponsored participants for the ISFM Africa conference.

Greatest value of the program

The greatest value of the programme has been the capacity development opportunities: both Kenyan and Swedish students have been exposed to international agricultural research for development activities and have worked in teams where they have been exposed to each other's countries' educational approaches. The joint supervision of students has also broadened the pedagogical skills of supervisors, as well as increased networking opportunities, which will lead to other collaborative ventures in the future.

A summary of the statistics for this project on p.165

Can integration of trees and crops contribute to enhanced agricultural productivity, resource utilisation and livelihoods for smallholder farmers? An evaluation of the multifunctionality of agroforestry systems

Project leader: Ingrid Öborn

Summary in Swedish

Kan integrering av träd och grödor leda till höjd produktivitet i jordbruket, ökat resursutnyttjande och högre inkomster för småbönder? En utvärdering av mångfunktionaliteten hos agroforestrysystem

I Afrika söder om Sahara har jordbruksproduktionen stagnerat eller minskat samtidigt som befolkningen har ökat. Detta har lett till brist på mark och mat, och har i stora områden bidragit till avskogning och markförstöring. Det behövs fler träd på gårdar och i jordbrukslandskapet för att producera ved, virke, foder och mat, och för att komma tillrätta med erosion och andra miljöproblem. Det skulle också bidra till att bygga upp kolförråd, markbördighet och andra ekosystemtjänster som bidrar till klimatanpassning.Detta projekt har studerat om integreringen av träd i jordbruket, som ett komplement till produktion av grödor och husdjur, kan bidra till att höja jordbrukets produktivitet och resursutnyttjande och därmed bidra till förbättrade levnadsvillkor för småbönder. Vi har utvärderat produktiviteten och mångfunktionaliteten hos agroforestrysystem i olika skalor (fält, gård, landskap), genom empiriska studier (mätningar, provtagningar, intervjuer) och har studerat böndernas förmåga att anpassa sig till klimatförändringar. Vi har också studerat vilka markegenskaper som krävs för att *Allanblackia*, ett afrikanskt träd med oljerika frukter som nu förädlas och anpassas för att kunna odlas av småbönder, ska trivas. Resultaten visar att i de områden i Kenya där studierna genomförts integrerar småbönderna träd i jordbruket för att producera olika varor och tjänster, och även för att öka anpassningsförmågan till klimatförändringar. De använder en rad trädarter, som har olika funktioner, för att erhålla synergier och minska konkurrensen med andra delar av produktionen. Projektet har genomförts i samarbete mellan SLU och partners i Kenya (Jomo Kenyatta University of Agriculture and Technology, Vi Skogen, the World Agroforestry Centre). Två doktorander har deltagit i arbetet och flera student- och utbildningsprojekt har genomförts. Vi har också deltagit i konferenser och anordnat kurser for rådgivare, bondeorganisationer och bönder.

Summary

More trees are needed on farms and in agricultural landscapes to produce firewood, timber, fodder, food, and to alleviate erosion and other environmental problems. Trees will also contribute to sequester carbon, build soil fertility and restore other ecosystem services, as well as contribute to climate change adaptation. This project has investigated whether the integration of trees in crop and livestock production can contribute to enhance agricultural productivity and resource utilization, and thereby contribute to improved living conditions for smallholders. We have evaluated the productivity and multi-functionality of agroforestry systems at different scales (field, farm, landscape) by empirical studies (measurements, sampling, interviews), and have surveyed farmers' strategies to adapt to climate change. We have also studied which soil properties are required for *Allanblackia*, an African tree with oil-rich fruits that are now being domesticated to be grown by smallholder farmers, to thrive. The results show that in the study areas, farmers are integrating trees into their production systems in order to get products and services including increased adaption capacity to climate change. They use a variety of tree species that have different functions in order to obtain synergies and reduce trade-offs with other farm components. This has been a collaborative project between SLU and partners in Kenya (Jomo Kenyatta University of Agriculture and Technology, the Vi Agroforestry and the World Agroforestry Centre-ICRAF). Two PhD students have participated in this work and several student and educational projects have been implemented. We have also participated in conferences and organized courses for advisors, farmers' organizations and farmers.

Background

The stagnated or declining agricultural production in sub-Saharan Africa, in combination with population growth, has resulted in shortage of land and food insecurity in many areas. Furthermore, increased pressure on natural resources has led to deforestation and land degradation that contributes to increase the vulnerability of small

Allanblackia – an oil tree crop under domestication.

Photo: ICRAF

holder farmers to climate change, often manifested as rainfall variability and extreme weather events. Low input of organic and inorganic fertiliser has led to nutrient depletion and reduced soil fertility. Declining trends in soil fertility and tree cover need to be reversed, and the resilience of the farming systems to climate variability and other stress factors must be enhanced, in order to improve productivity and livelihoods in the long term. To produce firewood, timber, fodder, food, and hedgerows for fencing, and to combat erosion and other environmental problems caused by deforestation, more trees are needed on farms and in agricultural landscapes. Trees will also contribute to sequester carbon, build soil fertility and restore other ecosystem services. There is an expressed interest from farmers in so called "agroforestry systems", i.e. farming systems that integrate crops and trees for multiple functions, often in combination with livestock production.

The current project was carried out in East Africa, mainly on smallholder farms in West and Central Kenya but also in Tanzania. The overall question has been: Can integration of trees on farms contribute to an enhanced agricultural productivity and resource utilization, and contribute to improved living conditions for smallholders? This has been evaluated in the different sub-themes described below.

Collaborators

SLU

Ingrid Öborn (project leader) – Dept. of Crop Production Ecology

Sigrun Dahlin, Minh Ha Hoang – Dept. of Soil and Environment

Mattias Jonsson – Dept. of Ecology

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

Catherine W Muthuri, Vivien Matiru, John Nyaga (PhD student, JKUAT/ICRAF)

Vi Agroforestry Programme, Kenya

Bo Lager (until November 2012), Ylva Nyberg (PhD student; Vi Agroforestry/SLU), Emmanuel Wachiye, Carolyne Musee, Amos Wekesa, Peter Wachira

World Agroforestry Centre (ICRAF), Kenya

Fergus L Sinclair, Edmundo Barrios

BSc/MSc/MFS (Minor Field Study) students

Kajsa Alvum-Toll, Helena Ström, Johan Fogelberg – MSc students at SLU

Ida Enjebo, Lisa Öborn – MFS students at Uppsala University

Josefine Winberg, Sabina Berntsson – BSc students at Lund University

Paul Cornelissen, Marjolene Blokland – MSc students at Vrije Universiteit Amsterdam

Approach

With the aim of assessing some of the multiple functions of agroforestry practices and to identify synergies and trade-offs at field, farm and landscape scale, we have used quantitative approaches [e.g. measuring of number, size and species of trees, crop biomass and yield (with main focus on maize), soil carbon, nutrient concentrations and stocks] and participatory methods (e.g. cropping calendar, farm-sketches, semi-structured interviews) as described under each sub-project below. We have also explored the roles of trees and farm management practices for climate change adaptation. Empirical on-farm biophysical and participatory studies were combined with on-station trial and modelling, e.g. of maize growth and the competition between different tree species and sizes of trees and maize for water, nutrients and light. The work includes research, education and extension activities. Student projects, training workshops and exchange of scientists have been integral parts of the project. Below follows a short description of the set-up of each study.

a) The first sub-theme studied farmers' strategies to adapt to climate change, in particular variability in rainfall and access to water. One study was carried out in a small watershed in Embu on the slopes of Mt Kenya, C Kenya, where the farming practices, land use and species diversity were compared on smallholder farms in one up-stream and one down-stream location. The research was led by Minh Ha Hoang who collaborated with Ida Enjebo, Lisa Öborn (MFS students) and researchers at ICRAF and JKUAT. Another study, carried out by PhD student Ylva Nyberg et al. in Western Kenya, aimed to determine which measures small-scale farmers use to adapt or cope with rainfall variability (used as proxy for climate change), score their efficiency and explore the rationale for farmers' choice of measure. 80 farmers (40 women,

40 men) in two geographical areas with different soil and climatic conditions were interviewed.

b) The second sub-theme, led by Ingrid Öborn, focused on the multiple functions of trees on farms and the synergies and trade-offs of trees in production systems. Studies were carried out at field, farm and landscape scale in five settlements in Trans Nzoia County, in the Rift Valley, Kenya, with similar soil and climatic conditions and well documented land use history (previously large farms dominated by maize mono-cropping). PhD student John Nyaga investigated the implications of small scale farming on tree diversity in maize-based systems as well as on the competition and/or synergies between different tree species and maize (124 study farms). Ylva Nyberg studied ecosystem services on farms of similar size (0.25-1 ha) but with different complexity, i.e. crop production with few or many trees, and crop and livestock production with few and many trees (4 farm types * 5 settlements = 20 farms). Under Ylva's supervision and within the same experimental design, three MSc students studied soil organic matter, i.e. carbon and nitrogen concentrations and stocks (Paul Cornelissen), soil aggregate stability (Marjolene Blokland) and water infiltration capacity (Johan Fogelberg). At the landscape level, land use and vegetation cover maps were produced for the five settlements by Mattias Jonsson in collaboration with ICRAF GIS lab and two BSc students (Josefine Winberg, Sabina Berntsson). The latter studied the influence of soil and water availability on land use and tree functionality (i.e. the functions the trees have on the farms and in the landscape.

c) The third sub-theme led by Sigrun Dahlin focused on *Allanblackia*. In order to create a sustainable supply chain of *Allanblackia* seeds, a domestication program has been initiated with ICRAF as a major research and development partner, and smallholder farmers as main stakeholders. This has resulted in high-potential germplasm and established propagation methods. However, the trees´ soil requirements need to be elucidated to realise the production potential. Within this project, and as a first step, two MSc students (Helena Ström and Kajsa Alvum-Toll) investigated the soil physical and chemical conditions and presence of symbionts in natural stands of *A. stuhlmannii* in Tanzania.

Scientific Results

Some key results from each sub-theme are given below and much more can be found in the listed publications.

a) *Climate change adaptation*. The 80 interviewed farmers in Western Kenya had an average landholding of 0.9 ha on which they grew an average of 4.5 different crop types, and kept two types of animals. Most farmers had only primary education; on average they were members of two farmers groups. The main rainfall-related challenges were too much or too little rainfall during different parts of the year in both geographical study areas. The most common adaptation measures were to carry out timely management, e.g. irrigate only in morning and evening and to plough and plant early in the season. However, the measures considered most effective were to use energy saving stoves, plant leguminous trees and preserve/store food. The least helpful measures were the ones that farmers sometimes were forced to use, such as selling harvest at non-profit, get relief food, work on another farm for money or reduce the number of meals per day. The reasons for not carrying out measures were mainly due to lack of money or knowledge. The results showed

Photo: Johan Fogde Dias

Kisumu, Kenya: Agricultural extension reaches only a few farmers in western Kenya.

"Joint supervision of students has been an efficient and productive way of building research collaboration that will continue beyond the project period"

Photo: Ingrid Öborn

Landscape view from the Kitale field site with Acacia trees in the forefront.

gender differences in measures and perceptions, e.g. being a member of, and getting help from a farmer group was ranked higher by women than by men, and women saw themselves as more vulnerable to climate change than men did. The two areas did not differ in terms of use of preventive adaptation measures, but the drier area (Nyando) had a higher use of forced measures to cope with crisis situations. Overall, access to advisory services significantly contributed to improved adaptation potential, and through using agroforestry practices, the potential was further enhanced.

b) *Multiple functions of trees on farms and the synergies and trade-offs of the trees in the production system.* The results from a survey of 124 farms located in transects across the five settlements showed that the average farm area was 0.9 ha. All farmers grew maize as their main crop and a majority (98%) intercropped maize and beans. Cow(s) were kept on most farms (80%) and the manure used on the crops (75% of the farms). 90% of farmers applied inorganic fertilizers during planting and as top dressing. Most farms (58%) had 5-100 trees/ha whereas the remaining farms had higher tree density. Mean species richness per farm was eight (max. 16) species. 38% of the individual trees counted on the farms were of indigenous origin (labelled with ⋆ below) whereas 62% were exotic. The ten most abundant species by ranking account for 96% of all trees on the farms: *Eucalyptus spp* (timber), *Sesbania spp*⋆ (fuel, soil fertility, fodder), *Grevillia robusta* (timber), *Cupressus lusitanica* (timber), *Markhamia lutea*⋆ (timber, multi-purpose), *Persia americana* (avocado, food), *Croton macrostachyus*⋆ (timber), *Calliandra calothyrsus* (fodder), *Psidium guajava* (fruit, food), *Eriobotrya japonica* (fruit, food). Tree species were planted for different purposes, in addition to supplying fire wood, and in different positions on the farm (e.g. boundary planting, wood lots, dispersed in crop field, homestead). *Eucalyptus spp* recorded highest species abundance at 57% (as boundary planting and in woodlots).

c) The natural stands of *Allanblackia stuhlmannii* in Tanzania grew on red strongly weathered soils, Ferralsols and Acrisols, with well-developed aggregate structure and high water infiltration capacity. The soils were highly acidic (<pH 4.5) with low nutrient (N, P) concentrations, especially below 10 cm depth. Arbuscular mycorrhizal (AM) fungi were observed on the sampled tree roots. A large num-

Diversified agricultural landscape (above left), dispersed inter-planting of N-fixing trees in a crop field (above right), soil properties and water availability (next page left) in a landscape transect walk (next page right) in a settlement in Trans Nzoia, Kenya.

ber of possible AM symbionts were also identified by molecular analysis. These results suggest that *A. stuhlmannii* is able to form AM, potentially with a wide range of fungal species.

In conclusion, farmers in the study areas are integrating trees into their production systems in order to get products and services, including an increased adaption capacity to climate change. They use a variety of tree species that have different functions in order to obtain synergies and reduce trade-offs with other farm components. Data collected from the field and farm studies, and the GIS-based maps of the settlements (e.g. vegetation cover) will be further used in simulation modelling of productivity, resource flows and trade-offs at different scales. The new knowledge obtained about growing conditions and symbioses in natural *Allanblackia* stands will be used in future domestication work.

Dissemination of results

Publications

The scientific results have been communicated at relevant conferences and symposia targeting policy makers, advisory organizations, researchers and other stakeholders. The results have also been used in training workshops organized within the project. Most conferences publish printed or on-line abstract proceedings, making the results readily available. The student reports are also easily accessible (or will be), e.g. from the Epsilon Archive for Student Projects (http://stud.epsilon.slu.se/). The two PhD students' theses each will consist of four peer-review papers/manuscripts, parts of which have been supported by this project. The goal is to compile all relevant results in peer-review manuscripts. We have also contributed to the production and publication of one book

Capacity development

PhD students. Parts of two PhD projects have been carried out within the project: "Impact of trees on water and nutrients dynamics in smallholder maize-based farming systems" (John Nyaga, JKUAT, Dept. Botany, subject Agro-ecology) and "Approaches for assessment of multi-functionality of agroforestry systems in Western Kenya" (Ylva Nyberg, SLU, Dept. Crop Production Ecology, subject Crop Production Science).

MSc, BSc and MFS students. Nine students, of which five carried out their MSc theses, have been linked to the research project as described above. The reports are listed among the publications.

Research training. Two Monitoring and Evaluation Officers at the Vi Agroforestry programme in Kenya (Emmanuel Wachiye and Carolyne Musee; at the Kitale and Kisumu projects, respectively) carried out research training corresponding to 3 months full-time per person during September 2012 to June 2013. The results were presented during the Agri4D Conference in Uppsala September 25-26, 2013.

Workshops and courses

In addition to some smaller workshops and meetings within the project two major training workshops have been organized:

1. *Training of Trainers on Sustainable Agriculture Land Use Management and Food Security,* Kisumu, Kenya, November 12th –15th, 2012. 30 participants from the Vi Agroforestry projects and other partner organizations in Kenya, Rwanda, Tanzania and Uganda.
2. *Training of Farmers on Productive and Sustainable*


Photos: Ingrid Öborn

farming in Trans Nzoia, Kitale, Kenya, April 22-25, 2013. 40 participants from Ylva Nyberg's 20 study farms. The training included feed-back from her 12 months study on their farms.

Conferences

Co-organizer of the *Integrated Soil Fertility Management Africa Conference* in Nairobi, Kenya, October 2012 (see p. 69). Project participants chaired two sessions and gave two oral and three poster presentations. In addition we sponsored five participants (end-users, advisors) from the Vi Agroforestry Programme in Kenya, Rwanda, Tanzania and Uganda to attend the conference and take part in the field trips. The project leader and the two PhD students participated with oral and poster presentations at *The SLU Africa Food Security Research Symposium in Kampala December 2012, the Agricultural Research for Development (Agri4D) Conference* in Uppsala 2011 and 2012, and the *SLU Global Food Security Research Symposium* in Uppsala, June 2013.

Gender aspects

We have successfully aimed at gender balance in the composition of the research team, and also when recruiting students and selecting participants/facilitators to conferences and training workshops. Gender aspects were taken into account in the research, and in some studies gender was a part of the design. Gender is mainstreamed in all work carried out by the NGO partner (Vi Agroforestry) and the scientists' and project workers' gender awareness were essential when selecting farm households and planning the training workshops. Traditionally women carry out most farm activities but they are not always in a position to make decisions and have ownership of land, cattle, money, etc. To encourage family members (often woman and man) to work together with enterprise development of their farm, two persons from each household involved in the study were invited to participate in the training workshops

Greatest value of the program

The project enabled us to build upon, and further develop, the partnerships between the research and development organizations that have been involved in implementing this project. The close interaction between research, capacity development and extension has been very fruitful, and of mutual benefit and learning for all parties. Joint supervision of students has been an efficient and productive way of building research collaboration that will continue beyond the project period. Thanks to the possibilities for collaboration between researchers and extension organizations, training workshops and outreach activities became more relevant for the target groups and reached many more endusers. The partnership also enriched the research and helped direct and prioritize the research objectives, ensuring scientific as well as practically applicable outputs and outcomes. Finally, the Minor Field Study (MFS) grant is a useful mechanism to involve students from Swedish universities. It is more difficult to engage students from African universities without specific fund allocation to cover tuition fees, project work etc. This is something that we suggest should be addressed in coming agriculture research for development programs.

A summary of the statistics for this project on p.166

Soil carbon, water infiltration and root competition: implications for management in African cropping and agroforestry systems

Project leader: Gert Nyberg

Summary in Swedish

Markkol, vatteninfiltration och rotkonkurrens; implikationer för skötsel av afrikanska grödo- och agroforestry-system

Många jordbruksmarker i Afrika är kraftigt degenererade. Kontinuerligt brukande av jorden, utan återförsel av näring och organiskt material, överbetning av kreatur och frånvaro av skyddande strukturer mot erosion har lett till utarmade, näringsfattiga, eroderade och lågproduktiva jordbruksmarker. Träd i åkrarna har ofta positiva effekter för markens bördighet, men de kan också utgöra konkurrenter till grödorna vad gäller ljus vatten och näringsämnen. I det här projektet har vi studerat landrehabiliterings- och landdegraderingsprocesser samt konkurrensförhållanden mellan träd och grödor för att bättre förstå och förbättra förutsättningarna för jordbruk och matproduktion.

Delprojekt 1 är en förlängning av ett tidigare påbörjat landrehabiliteringsprojekt i Lower Nyando, västra Kenya, samt en utvidgning av denna studie till Middle Nyando i samma del av landet. Preliminära resultat visar att vattnets infiltrationskapacitet ökade 3-5 gånger vid rehabilitering och 7-8 gånger i planterade träddungar, jämfört med kontrollytor. Kol, kväve och fosfor i marken ökade 50-100% på sex år. Resultaten analyseras nu ytterligare och kommer att publiceras inom kort.

Delprojekt 2 är en studie av landdegradering, i detta fall förändringar i viktiga markparametrar och skördeutfall under olika lång tid efter omvandling från tropisk skog till jordbruksmark i Upper Nyando. Genom att studera en 120 år gammal tidsserie har vi kunnat påvisa att utarmningen av jordbruksmark är en kontinuerlig process som går snabbast i början. Efter 40 år var infiltrationskapaciteten halverad och efter 120 år var den ca 15 % av vad den var i den orörda skogen. Kol och kväve i marken samt skördeutfall visade en likartad minskning över tid. Infiltrationskapaciteten ökade 3-5 gånger i landrehabiliteringsområden och 5-8 gånger i skogsområden (jämfört med kontrollerna). Markkol, -kväve och –fosfor ökade med 50-100%. Ökningen fortsatte under åtminstone sex år (d.v.s. från år 4-6). I Ochoria var infiltrationskapaciteten högre i terrasser än i närliggande icke terrasserade kontroller.

Delprojekt 3 är en utvidgning till Kenya av ett tidigare genomfört konkurrensförsök mellan träd och grödor i Burkina Faso. Preliminära resultat från isotopanalyser av mark- och rotrespiration visar att det är skillnader mellan olika träd både när det gäller deras inbindning av kol till marken och deras konkurrenskraft gentemot grödor. Data analyseras nu vidare och kommer att publiceras av SLU-ICRAF.

Sammantaget visar studierna inom detta projekt att det är möjligt att, genom aktiva och väl skötta landrehabiliterings- och markanvändningsåtgärder, relativt snabbt återställa markbördigheten och därigenom produktiviteten. Resultaten är viktiga för design och skötsel av agroforestrysystem.

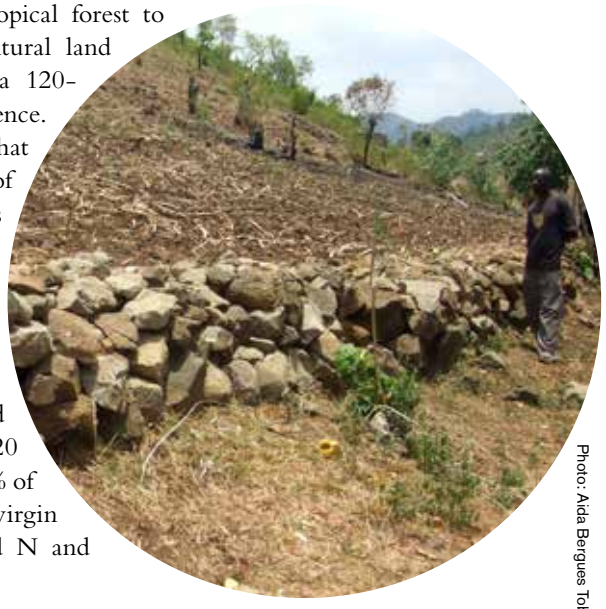
Summary

Many agricultural soils in Africa are seriously degraded. Continuous agriculture without replenishment of nutrients and organic material, overgrazing and lack of protective structures against erosion has lead to degraded, nutrient poor, eroded agricultural land with low productivity.

Trees in crop fields often have positive effects on soil protection and fertility, but they can also constitute competitors to the crop species regarding light, water and nutrients. In this project we have studied land rehabilitation and land degradation processes and competition between trees and crops with the aim to better understand and improve the conditions for agriculture and food production.

Land rehabilitation processes (subproject 1) is a prolongation of a previously initiated land rehabilitation study in Lower Nyando, western Kenya, and an extension of this study to Middle Nyando in the same part of the country. Preliminary results show that the water infiltration capacity increased 3-5 times in rehabilitation areas and 7-8 times in planted tree groves, compared with control areas. Soil C, N and P increased with 50-100 % during six years. The results are now being further analyzed and prepared for scientific publication.

Soil degradation processes (subproject 2) is a study of soil degradation processes Upper Nyando. Here we recorded changes in important land parameters and yield at different points in time during a transition from tropical forest to permanent agricultural land as evidenced by a 120-year chronosequence. We could show that the degradation of agricultural land is a continuous process that is fastest in the beginning. After 40 years the infiltration capacity was reduced to half and after 120 years it was ca 15 % of what it was in the virgin forest. Soil C and N and



Terrracing in Ochoria.

Photo: Aida Bergues Tobella

yields showed a similar decrease over time while bulk density increased. Infiltration capacity increased 3-5 times in land rehabilitation sites and 5-8 times under woodlots (as compared with paired controls). Soil C, N and P increased by 50-100%. The increase continued over at least 6 years (i.e. from year 4-6). In Ochoria infiltration capacity was higher in terraces than in adjacent un-terraced controls.

Tree crop competition (subproject 3) is an extension to Kenya of a previously conducted tree-crop competition trial in Burkina Faso. Preliminary data from isotopic analyses of soil and root respiration indicates that different tree species differ in both their carbon allocation to the soil and in their competitiveness to crops. Data is presently analyzed and will be published by ICRAF-SLU.

In conclusion, the studies within this project show that it is possible to restore soil fertility, and thereby productivity, by active land rehabilitation activities in a relatively short time. The results are important for the design and management of agroforestry systems.

Background

Much of the native forest in the highlands of western Kenya has been converted to agricultural land in order to feed the growing population, and more land is being cleared. In tropical Africa, this land use change results in progressive soil degradation, as the period of cultivation increases. Both rates and variation in infiltration, soil carbon concentration and other soil parameters are influenced by management within agricultural systems. Improving soil carbon and water infiltrability are key factors for improving agricultural productivity in degraded and erosion prone agricultural systems such as the Nyando basin in Kenya. The understanding of competition and/or ameliorative effects/synergies between trees and crops are fundamental in management of integrated agroforestry systems.

In fields with trees in the crop field, the isotopic composition of respired CO_2 will reveal the source of the respiration (C^3 from trees or C^4 from crops) and the mixture thereof, and thereby enabling calculations of competitive effects of trees on crops. Such knowledge and information is important for the design and management of agroforestry systems.

The research within the current project comprises an extension and expansion of two Sida-Formas funded research projects. The research included studies of:

1. Land rehabilitation processes – soil carbon sequestration in the Lake Victoria Basin in Kenya;
2. Soil degradation processes;
3. Tree-crop competition – the role of trees in the carbon budget.

Collaborators

SLU
Gert Nyberg, Aida Bargués Tobella (PhD student) – Dept. of Forest Ecology and Management

World Agroforestry Center (ICRAF), Nairobi, Kenya
Henry Neufeldt, Edmundo Barrios, John Nyaga (PhD student, also with Jomo Kenyatta University of Agriculture and Technology, Nairobi, Kenya)

Tropical Soil Biology and Fertility Institute of CIAT (TSBF-CIAT)
Bernard Vanlauwe

Wondo Genet College of Forestry (WGCF), Hawassa University, Ethiopia
Bekele Lemma

Institut de l'environnement et de recherches agricoles (INERA), Burkina Faso
Hughues Bazolé, Zacharia Gnakambary

Research Program on Climate Change, Agriculture and Food Security (CCAFS)/ The International Livestock Research Institute (ILRI), Nairobi, Kenya
James Kinyangi.

Approach

Land rehabilitation processes: Changes in various soil parameters over time were studied in a land rehabilitation project where grazing had been excluded and woodlots planted on farmland. Traditional soil water infiltration analyses and isotopic analyses of soil carbon were conducted: a) a revisit to the same fields in Lower Nyando, W. Kenya, i.e. to get one more point in time after seven years of land rehabilitation and agroforestry measures and b) an expansion of the sampling and analyses to Middle Nyando and temporally extended to include sampling six years after rehabilitation treatment. During field work for this purpose, we also got the idea and possibility for an additional study (see sub-project 2).

Soil degradation processes: Studies of different soil parameters and agricultural yield along a 120-year

chronosequence (history of conversion) from forest to agriculture in Upper Nyando. Changes were studied along the timeline during which they occurred. The studies were conducted together with James Kinyangi from CCAFS/ILRI.

Tree crop competition: Here competition between trees and crops were studied. With the aim of transfering novel methodology and technology to root competition studies in Kenya and Ethiopia, we conducted preparatory studies in Ethiopia on farmers' knowledge and perception of trees in crop fields. The intended instrumentation failed, however, and we instead we reverted to analyze the same things in Kenya only using another technology. This allowed for fewer samples to be collected and analyzed but the methodology was more robust. The data from this study is presently being analyzed and will be jointly published by ICRAF and SLU scientists.

Scientific results

Land rehabilitation processes: Infiltration capacity increased 3-5 times in land rehabilitation sites and 7-8 times under woodlots (as compared with paired controls). Soil C, N and P increased by 50-100%. The increase continued over at least six years (i.e. from year 4-6). These results show that it is possible to restore soil fertility, and thereby productivity, by active land rehabilitation. Preliminary results have been presented with posters at scientific conferences. The results are now being further analyzed and a manuscript is under preparation.

Soil degradation processes: (soil degradation processes). Along the 120-year chronosequence from forest to agriculture, infiltration, soil C and N decreased within 40 yr after conversion, while bulk density increased. Median infiltration rates fell to about 15% of the initial values in the forest, and C and N concentrations dropped to around 60 %, whilst the bulk density increased by 50 %. Despite high spatial variability, these parameters have correlated well with time since conversion and with each other. Food productivity (maize) followed a similar negative trend. These findings have been presented in poster form and published: *Soil property changes over a 120-yr chronosequence from forest to agriculture in western Kenya, G. Nyberg, A. Bargués Tobella, J. Kinyangi, and U. Ilstedt, Hydrol. Earth Syst. Sci., 2012, 16, 2085-2094.*

Tree crop competition: Although the intended technology did not function due to instrumental failure, preliminary results from studies using an alternative method indicate that different tree species influence the surrounding area differently when planted in crop fields. Data are currently being analyzed and a manuscript is under preparation in collaboration with ICRAF scientists.

Dissemination of results

Posters have been presented at three scientific conferences, IUFRO/FORNESSA (Nairobi), CIALCA (Kigali) and Agri4D (Uppsala). One scientific article (partly funded through this project) has been published and two are under preparation. Two seminars with local farmers were conducted in Ochoria and Nyando for dissemination and discussion of research results with 15-30 farmers at each. These farmers' seminars were much appreciated as exchange and learning opportunities by both researchers and local farmers. The results were also

Photo: Aida Bergues Tobella

Participant explaining at farmers workshop in Nyando.

Photo: Natxo Garcia

Participants in the workshop "Trees, soil fertility and erosion control" in Nyando.

"These results show that it is possible to restore soil fertility, and thereby productivity, by active land rehabilitation."

Photo: Aida Bergues Tobella

Farmer explaining good things concerning trees, Ochoria workshop.

presented at the ISFM Africa conference, which was sponsored by this project (see p. 69).

Gender aspects

The Swedish PhD student involved in sub-project 1 and 2 is female whereas the Kenyan PhD student who participated in sub-project 3 is male. Of the farmers participating in the seminars, more than 50% were female. Field assistants were both males and females.

Greatest value of the program

Apart from the scientific achievements the most valuable contributions are researchers' networking and participation in capacity development. Of most importance has been the establishment and maintenance of an active critical mass of development-oriented agricultural research in and for Africa at SLU. Equally important has been the maintenance of existing, and creation of new international research contacts as well as the contacts with local farmers who are the endusers of the knowledge generated.

For this project, the possibility to prolong and expand previous/already ongoing research activities has been very valuable. It has resulted in conclusions about duration of land rehabilitation effects and increased understanding of land degradation processes as well as preliminary results on tree-crop interaction. During a field trip in this project, a 25-year-old land rehabilitation project was revisited (Vi Agrofrestry). Changes in soil quality, agricultural production and socio-economic livelihood parameters were dramatic and obvious. This spurred the ideas for a multitude of research and for a multidisciplinary workshop. The workshop took place in Kitale, Kenya, in January 2013, and resulted in the formation of a research platform; 'The Triple L Initiative' [Land, Livestock and Livelihood Dynamics in Dryland Systems, West Pokot, Kenya (www.agri4d.se/document/Triple_L_concept_note.pdf)]. This initiative has already attained some national and international funding and it has generated a number of MSc student projects (Kenyan and Swedish) and several proposals for research project funding. Members of the Triple L Initiative are currently preparing a state of the art scientific article to be presented at the World Agroforestry Congress in New Dehli, India, in February 2014. This will also form the basis for field work in an upcoming international and multidisciplinary PhD course at SLU as well as further stakeholder/researcher workshops.

A summary of the statistics for this project on p.168

On the road to the Fure Headwaters Forest Reserve in Western Ghana.
Photo: Jan Willem de Besten

6. Gender and REDD+
Global instruments and changing environmental governance

Gender and REDD+
Global instruments and changing environmental governance

Project leader: Seema Arora-Jonsson

Summary in Swedish

Genus och REDD+: Globala instrument och en förändrad miljöförvaltning

Detta forskningsprojekt har undersökt hur klimatinstrumentet REDD+ (Reducing Emissions from Deforestation and Degradation), som en del av en allt mer "global" miljöförvaltning, förändrar förutsättningarna för människors vardag på landsbygden i Afrika. Studierna har genomförts i Burkina Faso, Tanzania och Ghana med delvis olika fokus i varje land. Vi har studerat hur frågor om genus hanteras i REDD+-program på policynivå (Burkina Faso), i genomförandet av pilotprojekt (Tanzania) och vilken roll icke-statliga aktörer såsom internationella NGOs (Non-Governmental Organisation) spelar i arbetet med jämställdhet i REDD+-processen (Ghana). Tack vare att studierna har genomförts på olika platser och haft fokus på olika nivåer (policy-global/nationell, NGO och by) har en förståelse uppnåtts för olika sätt på vilka genus förstås i REDD+.

Vi fann att:

1) Det nya är inbäddat i gamla sätt att arbeta. Nya metoder (t.ex. REDD+-politik) har omarbetats för att passa in som lösningar för tidigare utvecklings- och skogsfrågor. REDD+-ansträngningar för att få fler kvinnor aktiva på/involverade i lokala och globala marknader för skogsprodukter riskerar att förvärra en ojämlik arbetsfördelning, nu på en internationell skala. (Burkina Faso)

2) Statliga institutioner är föremål för ständig påverkan från icke-statliga aktörer när det gäller genus och skogsfrågor (t.ex. IUCN i Ghana som kan arbeta från global till lokal nivå) vilka inte kan ignoreras i planeringen av klimat- och skogsprogram.

3) På bynivå (i Tanzania) upplevde byborna de negativa effekterna av REDD+-programmet långt innan de hade möjlighet att se några positiva resultat. REDD-+ projekten ökade kvinnors arbete utanför skogen, vilket i sin tur ökade arbetsbördan för både kvinnor och män.

Summary

This research project has examined how climate change instruments such as REDD+[1], as part of the increasingly 'global' environmental governance, are changing the preconditions for men's and women's everyday lives in villages in Africa. The studies were carried out in Burkina Faso, Tanzania and Ghana with a different focus in each country. We studied how questions of gender are conceived in REDD+ programs at the policy level (Burkina Faso), in the implementation of pilot projects on the ground (Tanzania) and the role of non-state actors such as international non-governmental organizations (INGOs) in ensuring gendered concerns in the REDD+ process (Ghana). The multisite study and the attention to different levels (policy-global/national, intermediary-NGO and village level) give an understanding of the different ways in which gender is conceived in REDD+.

We found that:

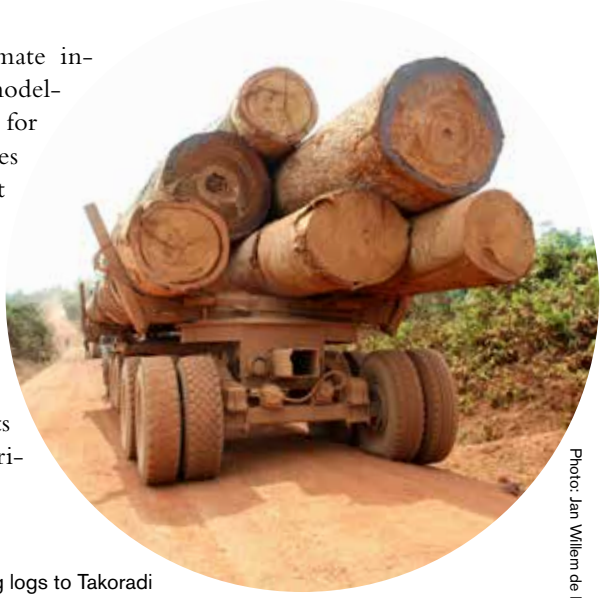
1) The new is very much embedded in old ways of working. New approaches (e.g. REDD+ policies) are reframed to fit in as solutions for old development and forest problems. REDD+ efforts to bring women into local and global markets for non-timber forest products risk reproducing and exacerbating an unequal gendered division of labor, now on an international scale. (Burkina Faso)

2) State institutions do not have the sole prerogative to decide on its gender and forest policy; they are subject to continuous influence from non-state actors (e.g. IUCN in Ghana that can operate at global to local levels), which cannot be ignored in planning of climate and forestry programs.

3) At the village level (e.g. in Tanzania), it appears that villagers were subject to the negative effects of REDD+ programs long before they had the possibility of seeing any positive outcomes. REDD+ project encouraged an increase in women's non-forest activities, mainly farming, which in the immediate future increased the workload for villagers.

Background

REDD+ is a climate instrument that is modelled as a Payment for Ecosystem Services scheme. To put it simply, the idea behind REDD+ is that countries, or as in our cases villagers in Africa, are paid for not logging their forests and thus contri-



A timber truck carrying logs to Takoradi port, Western Ghana.

Photo: Jan Willem de Besten

[1]REDD is the acronym for Reduced Emissions from Deforestation and Forest Degradation. REDD+ includes enhancement of forest carbon stocks and encompasses sustainable forest management and conservation of valuable forests, etc.

buting to carbon sequestration. To be feasible, REDD+ programs in many countries have tried to achieve some sort of congruence with the country's development goals.

This project is a study of REDD+ in three African countries, Burkina Faso, Ghana and Tanzania, and investigated:

• How do global climate instruments such as REDD+ change everyday lives for women and men in villages in Africa?

• More specifically the focus was on understanding how gender is conceived in these programs, that is, to study how these programs are gendered even when gender is not specifically mentioned.

By this we mean how dominant gender roles for men and women are reproduced or challenged by these programs. For example the idea of what is meant to be women's work and what is men's. The aim was to uncover if these programs entrench gender inequalities or if they can provide openings for gender equality.

Collaborators

SLU
Seema Arora-Jonsson (project leader), Andrea Petitt (PhD student), Yaw Yeboah (MSc student) – Dept. of Urban and Rural Development.

University of Ougadougou (UO), Burkina Faso
Mawa Karambiri (MA student) – Dept. of Sociology.

University of Gothenburg (GU), Sweden
Lisa Westholm (PhD student) – School of Business, Economics and Law (also in Burkina Faso).

Sokoine University of Agriculture (SUA), Tanzania
Beatus Temu (MSc student) – Dept. of Forest Economics. Beatus finished his MSc as a part of the project. Currently, he is Research and Monitoring officer with Green Resources, which is a forest plantation, carbon offset, forest products and renewable energy company, operating in Tanzania, Mozambique and Uganda.

Approach

We focused on three different levels in the countries that we studied:

Policy level

In Burkina Faso, the study focused on the REDD+ policy process, that is, REDD+ negotiations among the Ministry of Environment and Sustainable Development (Ministère de l'Environnement et du Dévelopement Durable), World Bank, officials from other ministries in Burkina Faso, donor agents, the private sector and civil society actors. We carried out interviews, participant observation at meetings and workshop (Oct. 2011, Feb. and Nov. 2012) and a review of official documents related to REDD+ generally and on Burkina Faso in particular. The research team included PhD student Lisa Westholm and MA student Mawa Karambiri.

Non-state actors

In Ghana we undertook a study of the International Union for the Conservation of Nature's (IUCN) strategy called the Gender Road Map for REDD+. The Gender Roadmap is a strategy for mainstreaming gender concerns in national REDD+ strategies. Interviews were carried out with IUCN workers in the capital, Accra and with officials of the Ministry for Women and Children as well as during field visits to villages where IUCN has projects. The research team included PhD student Andrea Petitt and Beatus Temu who completed his MSc thesis *Carbon business scenarios and communities' choices under REDD+ in Lindi Rural District, Tanzania, 2012* as part of the project.

Pilot projects in villages

In Tanzania, we focused the study on REDD+ implementation in two villages of Lindi Rural District (Kinyope and Likwaya). The methods we used here were participant observation at village meetings, focus group/individual interviews with men and women about their daily lives before and after the introduction of the REDD+ project and with district officials and the NGO (The Tanzania Forest Conservation Group) implementing the REDD+ project. The research team included Yaw Yeboah who completed his MSc thesis *Gendering the REDD+ policy process in Ghana* as part of the project.

Scientific results

Policy level – Burkina Faso

• In following the REDD+ policy process, we found that what might appear to be new ideas about climate mitigation are actually embedded in old ways of working. New actors and new directions in (REDD+) policy were reframed to fit in as solutions for old development and forest problems. For example in Burkina Faso the hope is that their participatory forest management schemes will be the basis of the REDD+ process, which is very much business as usual.

What was new however are the intensified ef-

forts to bring women's work with Non Timber Forest Products into local and global markets, now that the use of timber from the forests is restricted. A great deal of gender research in the past on women's entry into markets supports our conclusion that without accompanying social policy that protects women's interests, REDD+ plans risk reproducing and exacerbating an unequal gendered division of labor, this time on an international scale. For a detailed analysis of this argument see the submitted paper: *Defining Solutions, Finding Problems: Deforestation, Gender and REDD+ in Burkina Faso.*

Non-state actors – Ghana

• The study of the implementation of the gender roadmap for REDD+ showed very clearly that state institutions do not have the sole prerogative to decide on its gender and forest policy. They are subject to continuous influence from non-state actors. For example the study shows how the IUCN operates at many levels, from global to local arenas that are not easily accessible to national governments. These organizations can no longer be ignored in the planning of climate and forestry programs. For more information see the MSc thesis: *Gendering the REDD+ policy process in Ghana.*

Pilot projects in villages – Tanzania

• The studies of the pilot project in Lindi Rural District show that villagers were subject to the negative effects of REDD+ programs long before they had the possibility to experience any positive outcomes (e.g. their inability to use the forest for everyday subsistence). The REDD+ projects encouraged an increase in non-forest activities, mainly farming, which caused pressure on land and for land. This resulted in a change in the labor patterns since it was generally men who worked in the forests with timber and cannot do so any longer. Neither did they feel that they could take on women's chores. These pressures are giving rise to discontent in the villages. In general it appears that there is an increase in the workload for both women and men in the villages and a lack of alternative livelihoods. See the report *The implication of gendered division of labour for the introduction of REDD+ in Lindi Rural District, Tanzania.*

Overall conclusions

1. There are very different views among the various actors about REDD+ and a great deal of confusion. Seen in a larger perspective different interests seem to be working together nonetheless, including the villagers who are negatively affected but hope for future advantages. At the moment it seems that confusion or the vagueness of REDD+ programs has led to some sort of consensus on the benefits of REDD+ programs to promote both climate and development aims.

2. Villagers are being brought into global orbits to manage, protect and conserve what are increasingly becoming a global commons, where not only the villagers themselves but a host of other people are deciding on how the land is used. The villagers do this not entirely as unwilling subjects but with hopes for future compensation.

3. REDD+ programs are seeking to include women in larger economies without any associated social policy that safeguards their interests. The real transformation is thus not in developmental goals as is stated in many REDD+ policy documents but in efforts to peg women's labour to global markets. The discussion on gender and REDD+ has become mainly one of how best to use women's labour in the REDD+ process. For those wanting to ensure greater equality in these climate programs we cannot just look to states for social policies. We need to look beyond to the somewhat more shadowy contours of global governance and identify actors in each situation

Dissemination of results

Publications

Two peer-review articles are under review and preparation: *Defining solutions, finding problems:*

Photo: Rashidi Lindonde

MSc student Beatus Temu during forest invetory survey in Kinyope village forest. The forest has been set aside by the villagers for REDD+ project.

"REDD+ plans risk reproducing and exacerbating an unequal gendered division of labor, this time on an international scale"

Photo: Beatus John Temu

The Village Executive Officer (lady standing) in Likwaya village talking to villagers during REDD+ revenue distribution, as coordinated by TFCG-MJUMITA REDD+ project in Lindi, Tanzania.

Deforestation, gender and REDD+ in Burkina Faso submitted to journal, Conservation and Society and *Climate instruments and global governance: new public spaces and notions of citizenship* that is under preparation. In addition a report from Tanzania, *The implication of gendered division of labour for the introduction of REDD+ in Lindi Rural District, Tanzania* has been presented at an international conference in Wondo Genet, Ethiopia and generated a great deal of interest. Ethiopian colleagues requested for further presentations at Wondo Genet in the future.

Two MSc theses were written as part of the project, *Gendering the REDD+ policy process in Ghana, 2012* by Yaw Yeboah (Department of Urban and Rural Development, SLU) and *Carbon business scenarios and communities' choices under REDD+ in Lindi Rural District, Tanzania, 2012* by Beatus Temu at Sokoine University of Agriculture, Morogoro, Tanzania.

Capacity building

Along with the two SLU students involved in the project, two masters' students, Mawa Karambiri from UO and Beatus Temu from the SUA, took part in the PhD course, Gender, Development and Environmental Governance (7,5 ECTS), 10 September – 12 October, 2012 at SLU, Uppsala.

Presentations of papers from the project were also given at the 7th International Conference in Interpretative Policy Analysis, University of Tilburg, the Netherlands, 5 – 7 July, 2012, Tilburg and at the IUFRO, International Union of Forest Research Organizations' Gender and Forestry Conference, Environmental governance and four decades of gender research: Where do we stand? 27 - 29 November, 2012, Wondo Genet Forestry College, Ethiopia. The conference was organized partly by funds from the project and involved students and teachers at the Wondo Genet Forestry College in a discussion on gender and forestry.

The greatest value of the program

The greatest value of this research project was that it brought together researchers working in Sweden and those in the three African countries where we carried out our studies; this led to very fruitful interactions. This was especially important as it was on gender research that many can see is central to outcomes of development projects and unfortunately has had little place in forest and agricultural curriculum and research so far. Since the project was focused on promoting young researchers, it has also contributed to a critical mass of young scholars eager to work on the social, political and economic implications of climate change and its policies.

A summary of the statistics for this project on p.169

7. Expanding cassava production and accelerating commercialization – from breeding to product development

Kanakantapa Women's Cassava Project, outside Lusaka, Zambia
Photo: Görrel Espleund

Photo: Görrel Espelund

Fresh cassava roots from the market.

Synthesis

While cassava's importance is increasing in Africa it is also prone to attacks by pests and diseases as well as post-harvest physiological deterioration. To secure the role of cassava as a food crop, and to ensure that cassava will continue to be an important source of income for rural farmers, the research and breeding have to emphasize improved root quality, root yield and resistance to pest and diseases. Furthermore, in order to capitalize on cassava's multiple functions as a nutritious food, there is continued need for educating and informing precisely about cassava and its inherent toxicological components. Understanding cassava food safety is important as this is possibly the main reason why cassava was domesticated. It is the only staple crop that contains naturally occurring toxicants. Identification of superior genotypes in farmers' fields for multiplication, dissemination, production and as genetic sources in participatory breeding programs, are therefore necessary in order to develop a sustainable agriculture in Africa. More productive cassava varieties have been transferred from West Africa to the rest of Africa's cassava belt. Farmers have responded to productivity gains and growing markets by increasing cassava production and sales. Small and medium-scale traders and processors have emerged to experiment with cassava-processing ventures.

The two subprojects on this theme have used a value chain approach for cassava breeding, commercialization and promotion. The first sub-project aimed at investigating genetic diversity of cassava cultivated by farmers in Vietnam and to collect information through interviews with farmers regarding their practices and opinions on cassava cultivation. The findings were evaluated in a comparative study with results from previous cassava diversity studies in Uganda. Based on the farmers' naming of their cultivated varieties the number of cassava varieties was fairly low per farmer (2 to 4 varieties per farmer) in northern Vietnam in comparison to previous findings in Uganda. Local and improved varieties were cultivated in separate plots often on a larger area for the improved varieties. The improved varieties, that were all bitter i.e. contained cyanogenic glucosides, had a higher yield, but the local so-called sweet varieties were kept for their high cooking qualities. The improved varieties were either utilized as animal feed, for local ethanol production, for starch produced locally and sold to re-sellers, or sold directly to the market as fresh or dried cassava. DNA sequencing revealed novel taxonomic units, as well as previously known mycorrhiza species, and differences in these in relation to soil. The project contributes to the understanding of desired breeding goals of farmers, their use of local varieties and adoption of improved varieties, which are important factors when considering future breeding of cassava.

In the second sub-project the aim was to clarify how expanding cassava production enhances commercialisation along the value chain. The results suggest that cassava markets are emerging slowly in southeastern Africa, in part because the region's heavy cassava production zones lie far from major food processing industries found in the capital cities and large urban markets of the maize belt. Moreover, as a result of emerging markets, shipping cassava products from the cassava belt to maize-belt cities, issues of food safety and limited processing technologies have increased. Because some cassava varieties contain substantial quantities of cyanogenic glucosides that render them toxic for humans and animals, processing cassava into ready-to-eat products requires the removal of cyanogens and other anti-nutrients. Unlike West Africa, where cassava commercialization has been driven by urban demand facilitated by the availability of affordable technologies for processing convenience foods in cassava-belt cities especially gari, the emerging cassava markets in southeastern Africa have centered on fresh cassava markets, low value-added cassava flour, and experiments in industrial processing of cassava-based starches, biofuels and feeds. The studies conclude that further research is required on characterising the biochemical, viscoelasticity and physico-chemical properties of the various cassava varieties and the mapping of their possible applications in product development of foods, feed as well as other industrial applications.

Linley Chiwona Karltun (coordinator)

Identification of cassava varieties meeting farmers' preferences for participatory breeding

Project leader: Anna Westerbergh

Summary in Swedish

Deltagande förädling – på jakt efter kassava med önskade egenskaper bland småböndernas lokala sorter

Kassava odlas främst för sina ätbara stärkelserika rötter och spelar en betydelsefull roll för livsmedelsförsörjningen i tropiska Afrika, Latinamerika och Asien. Kassava är en viktig basgröda för småskaliga lantbrukare och eftersom den kan säljas på marknader ger den också förbättrade möjligheter till försörjning. Kassava kan odlas i icke-bevattnade och resurssnåla odlingssystem, åtminstone delvis tack vare en utvecklad symbios med mykorrhizasvampar. Målen med detta tvärvetenskapliga projekt är 1) att undersöka den genetiska mångfalden hos såväl den kassava som odlas i Vietnam som deras mykorrhizasymbionter, och 2) att samla information om lantbrukarnas odlingsmetoder och erfarenheter av kassavaodling. Resultaten har jämförts med resultat från motsvarande studier i Uganda, genomförda av oss 2002-2004.

Resultaten indikerar att antalet kassavasorter per lantbrukare i norra Vietnam är lågt i jämförelse med Uganda. Ytterligare genetiska analyser av mångfalden inom och mellan lantbrukarnas sorter kan bekräfta deras identifiering eller också visa på ytterligare mångfald. I norra Vietnam odlas lokala och förbättrade sorter i separata fält, där förbättrade sorter ofta odlas på större områden. De förbättrade sorterna, som i denna studie alla var bittra, odlas på grund av en högre avkastning, medan de lokala så kallade söta sorterna odlas för sina goda matlagningsegenskaper. De förbättrade sorterna används som djurfoder, för lokal etanolproduktion, för lokal produktion av stärkelse som säljs till återförsäljare eller för försäljning av färsk eller torkad kassava direkt till marknaden. Studien påvisade ett samband mellan å ena sidan mångfald av kassavasorter, jordegenskaper och geografi och å andra sidan mångfald och artidentitet hos nyttiga mykorrhizasymbionter i lantbrukares fält. DNA-sekvensering visade på förekomst av såväl nya taxonomiska enheter av mykorrhizasvampar som redan kända arter, samt skillnader mellan odlingsplatser.

Sammanfattningsvis bidrar projektet till förståelsen av vilka förädlingsmål som kassava-lantbrukarna har, samt i vilken omfattning de använder lokala respektive förbättrade sorter. I det framtida förädlingsarbetet är detta viktiga faktorer att ta hänsyn till.

Summary

Cassava is mainly cultivated for its edible starchy roots and plays an important role in food security in tropical Africa, Latin America and Asia. Cassava is an important subsistence crop which can also be sold at markets, thereby offering improved livelihood opportunities to small-scale farmers. Cassava can be cultivated in rain-fed and low-input agro-systems, at least partly thanks to a symbiotic relationship with mycorrhizal fungi. The objectives of this interdisciplinary project were to investigate 1) the genetic diversity of both the cassava cultivated in Vietnam and their mycorrhiza symbionts, and 2) to collect information about farmers' practices and opinions on cassava cultivation. The findings have been evaluated against the results from comparable studies previously conducted in Uganda.

This study indicated that the number of cassava varieties per farmer is fairly low in northern Vietnam in comparison to Uganda. Further genetic marker analysis of the diversity within and between farmers´ varieties can confirm farmers´ identification or reveal additional diversity. In northern Vietnam, local and improved varieties are cultivated in separate plots, where improved varieties are often cultivated in larger areas. The improved varieties, which were all bitter, are cultivated because of the higher yield, while the local "sweet" varieties are kept for their high cooking qualities. The improved varieties were either utilized as animal feed, for local ethanol production, for local production of starch to be sold to re-sellers, or as fresh or dried cassava sold directly at the market. The study demonstrated a link between, on the one hand the diversity of cassava varieties, soil properties and geographic distribution, and on the other hand diversity and species identity of the beneficial root symbiosis arbuscular mycorrhiza in farmers' fields. The DNA sequencing revealed novel taxonomic units as well as previously known

Discussion with farmers in Northern Vietnam during harvesting of cassava.

Photo: Per-Olof Lundquist

mycorrhiza species, and differences among fields.

In conclusion, the project contributes to the understanding of farmers' breeding goals and their use of local varieties and adoption of improved varieties – two factors that are important to consider in future cassava breeding endeavors.

Background

Plant breeders often work in relative isolation from their target group, i.e. farmers, and they have sometimes been unaware of farmers' multitude of preferences, beyond yield and resistance to diseases and pests. This lack of communication may result in a low adoption rate of improved varieties by farmers. For any successful breeding program that involves the development, dissemination and adoption of new varieties, it is of great importance to have knowledge about the genetic composition of varieties in farmers' fields, the farmers' preferences, and their cultivation practices.

In Vietnam, cassava breeding activities started in 1975 after the unification of the country. Today, almost 40 years later, knowledge about how successful the cassava breeding activities have been is lacking, both from a farmer production perspective and from a gene conservation perspective. Have these improved varieties been adopted by farmers? Are there qualities/traits desired by farmers that are not harbored by the new varieties? How has the dissemination of a few improved varieties affected the cassava genetic diversity and the variety composition on farmers' fields? To answer these questions our research team has combined farmers' interviews, field observations and genetic analyses of Vietnamese farmers' cassava varieties. We have previously used a similar interdisciplinary approach for studying diversity of farmers' fields in Uganda. Uganda has a longer history of cassava cultivation and breeding than Vietnam and has suffered from severe outbreaks of cassava diseases. The overall goal of this project was to carry out a comparative study between these two countries.

Furthermore, cassava can be cultivated in rainfed and low-input agro-systems, but is often claimed to cause soil degradation. Like most plants, cassava can form the beneficial root symbiosis called arbuscular mycorrhiza. Since cassava is generally cultivated in soils with a low nutrient content this beneficial trait is needed in order to achieve sustainable and secure cultivation of cassava. Nevertheless are root traits often overlooked in breeding programmes. Our purpose is to provide knowledge about the link between the diversity of cassava varieties, soil properties and the diversity of arbuscular mycorrhiza symbionts.

The study of cassava in farmers' fields in Vietnam was initiated during this program and several of the research activities will continue thanks to additional funding from Sida-Formas.

Collaborators

SLU

Anna Westerbergh (also at the Linnean Center for Plant Biology, Uppsala, Sweden) – Dept. of Plant Biology and Forest Genetics

The Plant Resources Center, Vietnam Academy of Agricultural Sciences, Hanoi, Vietnam

Vu Linh Chi and Hoang Thi Nga

Approach

Farmer interviews: Interviews with farmers and collection of farmers' varieties were conducted in a total of six villages in northern, central and southern Vietnam; two villages from each region. Three farmers in each village were selected for in-depth interviews. The same set of questions concerning for example naming, origin and morphological description of the grown varieties, primary use, desirable traits and cultivation practices were put to each of the farmers.

Plant collection and genetic analysis: Each farmer was asked to identify and name the different varieties cultivated in her/his cassava field. Leaves were collected from 15 plants of each farmed variety. To determine the genotype of each of these plants DNA will be extracted and analyzed using genetic marker analysis in a follow-up study of this program. The genetic analysis, based on genetic markers, is used to distinguish different varieties of cassava from each other. Thirty genetic markers that are distributed over the cassava genome are used. This provides information that can show relatedness among the collected samples. The result obtained makes it possible to identify the cassava varieties used and named by different farmers. It also shows the genetic diversity in the cultivated fields, and can possibly demonstrate an additional unknown diversity. This will help us understand the farmers' management of their cassa-

va varieties i.e. how they maintain and separate varieties. Furthermore, within the framework of the follow-up studies, genotypes of improved varieties from cassava breeding programs in Vietnam will be compared with genotypes of the plants collected in farmers' fields to study dissemination and adoption rate of improved varieties.

Soil, root collection and mycorrhiza analysis: Roots and surrounding soil of the same plants that are genotyped have been collected and analyzed for diversity of mycorrhiza.

Scientific results

Farmer interviews: The interviews with farmers and field observations revealed that the upland farmers in northern Vietnam cultivate a relatively small number of varieties (2 to 4 varieties per farmer) compared to the Ugandan farmer (at least 5 varieties per farmer). In Vietnam, the different varieties are furthermore cultivated in separate plots and occasionally intercropped with maize, forest or fruit trees (lychee). The Vietnamese farmer grows both improved and local varieties (varieties that have been grown continuously for over one farmer generation in the area) – often on a larger area for the improved varieties. The improved varieties are not named by its series number given by the breeding program, but instead the farmers give all varieties names both in Vietnamese and in their local language. The name usually describes a morphological trait that is characteristic for a particular variety. Similar to Ugandan farmers, the Vietnamese farmers are able to describe and differentiate the varieties based on the leaf, stem and root morphology and the taste of the tuberous roots. The tuberous roots of all improved varieties were described by the Vietnamese farmers as bitter, i.e. containing high levels of the toxic compounds cyanogenic glucosides, while the local ones were described as sweet tasting, i.e. tuberous roots containing low levels of cyanogenic glucosides. In Uganda, on the other hand, almost all varieties were described as sweet tasting. The participating Ugandan cassava farmers were cultivating a mixture of local and improved sweet varieties in the same field, but also a number of unnamed varieties of unknown origin. These mixed stands were grown with other crops such as bananas, beans or the cereal grains millet, sorghum or maize. The variety composition and frequency of improved and local varieties differed extensively among villages and we found a surprisingly high genetic diversity both within and among Ugandan farmers' varieties. This may reflect the diverse needs and changing circumstances characteristic of traditional farming systems.

According to the Vietnamese farmers the improved varieties have a higher yield than the local varieties, partly because the local ones are only harvested in the second year. However, the local sweet varieties are kept for their high cooking qualities and they are the only varieties used for human consumption. The improved varieties, which are all bitter, are either utilized as animal feed, for local ethanol production, for local production of starch to be sold to re-sellers, or as fresh or dried cassava sold directly at the market. Based on the farmers' naming of their cultivated varieties, it seems like some varieties are grown by several farmers in the same village. However, which cassava varieties the farmers are cultivating differ widely among villages.

Soil, root collection and mycorrhiza analysis: The DNA sequencing revealed novel operational taxonomic units as well as previously known species of the symbiotic fungi; furthermore we found differences among the fields.

In conclusion, this comparative project on cassava in farmers' fields contributes to the understanding of farmers' desired breeding goals, their use of local varieties and adoption of improved varieties in two countries (Vietnam and Uganda) with different agricultural and breeding histories. These factors are important to consider in future cassava breeding that involve development, dissemination to farmers and enhanced adoption of improved varieties. Finally, to obtain effective and successful cassava breeding programs, a close collaboration between farmers, researchers and breeders at different stages of the research process is needed. Hopefully, an awareness of the benefits and potential pitfalls that have resulted from the relatively recent expansion of cassava cultivation in Vietnam can be valuable in planning the expansion of cassava cultivation in Africa, and thereby contribute to improved food security.

Dissemination of results

The knowledge obtained in this project is relevant for farmers, breeders and agriculture extension services promoting cassava cultivation in tropical and subtropical regions on all continents. Our results will be communicated to staff at agricultural

"This project contributes to the understanding of farmers´ desired breeding goals, their use of local varieties and adoption of improved varieties"

Photo: Anna Westerbergh

Drying of cassava chips.

departments in the different provinces, districts and communes. Our collaborators will inform local farmers during field courses and testing of breeding material. Publications regarding both cassava and arbuscular mycorrhiza are planned for publication in peer-reviewed international journals. Findings will be translated to Vietnamese and published in a popular science journal and/or pamphlet. Results have been/will be presented at international and national conferences. Exchange of knowledge and experiences between our colleagues in Vietnam, the farmers and ourselves has been extremely valuable for the project and has also given us an opportunity to contribute to the ongoing process of capacity development. This exchange has occurred through visits at SLU, the collaborating institute in Vietnam, the farmer villages and field studies. Furthermore, our established collaboration over many years with the International Center for Tropical Agriculture (CIAT) in Colombia, also strongly involved in the cassava breeding activities in Vietnam, and recent collaboration with the International Institute of Tropical Agriculture (IITA) will facilitate the transfer of our knowledge to the farmers and cassava community. The knowledge can be implemented in ongoing or future cassava breeding programs by the Vietnam Academy of Sciences and by IITA in Uganda and other African countries.

Gender aspects

Researchers of both genders on all levels, from students to established researchers, were highly involved in the project and their contribution was a necessity for carrying out the project. Both female and male farmers were interviewed and involved in field observations in the different villages. Our interviews and field studies show that especially the female farmers are deeply involved in cassava management and cultivation and their knowledge has contributed a lot to our understanding of cassava diversity and cultivation in Vietnam. The appreciation we showed for these farmers' knowledge was highly valued, and seemed to boost their self-esteem.

Greatest value of the program

The program made it possible to compare the farmers' conditions for cultivating and managing cassava in two countries in different continents (Asia and Africa), and to evaluate recent breeding activities in Vietnam against the situation in Uganda. It was also possible to carry out novel characterization of root symbionts in relation to cassava genetic diversity. As mentioned, the project will continue thanks to funding from Sida-Formas.

A summary of the statistics for this project on p.170

Expanding cassava production and accelerating commercialisation in southern Africa – adding value through product development

Project leader: Linley Chiwona Karltun

Summary in Swedish

Utökad produktion av kassava och snabbare kommersialisering i södra Afrika – värdeökning genom produktutveckling

Det övergripande målet med denna forskning var att klargöra hur ökad produktion av kassava leder till kommersialisering längs en värdekedja. Detta uppnåddes genom inventerande studier med bönder, analyser av halterna av cyanogena glykosider i kassavaprodukter (för att undersöka deras eventuella hälsovådlighet), samt dokumentation av pågående processer för och effekter av kassavakommersialisering. Resultaten indikerar att marknader för kassava ökar sakta i sydöstra Afrika, delvis därför att regionens produktionsområden för kassava ligger långt från förädlingsindustrierna i större städer och marknadscentra, vilka är koncentrerade till ländernas majsbälten. Med ökande kassavahandel i städerna har det uppstått problem som har att göra med livsmedelssäkerhet, bland annat på grund av att det finns begränsade resurser för förädling av kassava. Vissa typer av kassava innehåller stora mängder cyanogena glykosider (blåsyra), vilket gör dem giftiga för människor och djur. För att kunna ätas måste kassava renas från cyanogener och andra skadliga ämnen. I Västafrika har kommersialiseringen av kassavaprodukter drivits av efterfrågan i städerna, varigenom kostnadseffektiva förädlingsmetoder för konsumtionsfärdiga livsmedel har utvecklats, särskilt för den västafrikanska rätten gari. I Södra Afrika har i stället de framväxande marknaderna centrerats runt färsk kassava, enkelt kassavamjöl och försök med framställning av stärkelse, biobränslen och djurfoder. Mer forskning behövs för att beskriva biokemiska egenskaper för olika varianter av kassava, samt deras möjliga användningsområden som livsmedel för människor och foder för djur, samt för andra industriella användningar.

Summary

The overall aim of this research was to clarify how expanding cassava production enhances commercialisation along the value chain. This was achieved by conducting inventory studies with farmers, analysing cyanogenic glucoside levels in cassava products to ascertain safety as well as documenting the ongoing processes and effects of cassava commercialisation. The results suggests that cassava markets are emerging slowly in southeastern Africa. This is partly due to the fact that the region's heavy cassava production zones lie far from major food processing industries found in the capital cities, and large urban markets of the maize belt. Moreover, as markets emerge shipping cassava products from the cassava belt to maize-belt cities, issues of food safety and limited processing technologies have emerged. Because some cassava varieties contain substantial quantities of cyanogenic glucosides that render them toxic for humans and animals, processing cassava into ready-to-eat products requires the removal of cyanogens and other anti-nutrients. Unlike West Africa, where cassava commercialization has been driven by urban demand facilitated by the availability of affordable technologies for processing convenience foods (e.g. gari) in cassava-belt cities, the emerging cassava markets in southeastern Africa have centred on fresh cassava markets, low value-added cassava flour, and experiments in industrial processing of cassava-based starches, biofuels and feeds. Further research is required on characterising the biochemical properties of the various cassava varieties, and mapping their possible applications in product development of food, feed as well as other industrial applications.

Background

Cassava awareness and utilization is on the rise in Africa. For the last 50 years policy makers have been preoccupied with increasing the production of maize, wheat and rice to feed the growing urban population at the expense of crops such as cassava. The high productivity of modern cassava varieties developed by breeders in the 1970ies and 80ies in West Africa has resulted in low production costs per unit of

Fresh cassava roots.

Photo: Anna Westerberh

carbohydrate, thereby opening profitable commercial opportunities for cassava-based food, feed and starch. As more productive cassava varieties have been transferred from West Africa to the rest of Africa's cassava belt, farmers have responded to productivity gains and growing markets by increasing cassava production and sales, also known as the Cassava Transformation in Southeastern Africa (CATISA). Small and medium-scale traders and processors have emerged to experiment with cassava-processing ventures. Rapid urbanisation and rising incomes suggest that urban demand for convenience and high-value processed foods will increasingly dominate African food markets. Our studies on promoting cassava commercialisation through investments in cassava production, food safety, food technology and product development aim to increase awareness and utilisation of cassava by farmers, processors, traders, the public and the private sector. The ultimate goal is to contribute towards food and nutrition security of households, especially the resource poor households in need of food and dietary diversification.

To conduct these studies a multi-pronged institutional and multidisciplinary approach was used. The lead institution was SLU in close partnership and collaboration with a large number of partners (see below).

Collaborators

SLU
Linley Chiwona Karltun (project leader) and Thao Thi Phuong Vuong (MSc student) – Dept. of Urban and Rural Development, Uppsala, Sweden

University of Zambia
Drinah Banda Nyirenda (CATISA coordinator in Africa) and Cornelius Mwansa Nkonkola (MSc student) – Dept. of Animal Nutrition and Food Sciences, Lusaka, Zambia

University of Ghana
Emmanuel Ohene Afoakwa, Agnes Simpson Budu (MSc student) and Clement Asiedu (MSc student) – Department of Nutrition and Food Sciences, Legon, Ghana

University of Copenhagen
Leon Brimer – Department of Veterinary Disease Biology, Copenhagen, Denmark

International Institute for Tropical Agriculture (IITA), The Southern Africa Root Crops Research. Network (SARRNET), Lilongwe, Malawi
Pheneas Ntawuruhunga

Uppsala University
Thao Thi Phuong Vuong (MSc student) – Dept. of Earth Science

Rural Women Foundation, Arnhem, The Netherlands
Uzo Klein Leugemors

Programme Against Malnutrition, Lusaka, Zambia
Maureen Chitundu

Lund University – Department of Human Geography
Magnus Jirström

Instituto de Investigação Agrária de Moçambique (IIAM)
Annabela Zacarias

National Agricultural Research Organisation (NARO), Entebbe, Uganda
Yona Baguma

Michigan State University, East Lansing, USA
Steve Haggblade and Felix Nweke

Chinangwandi Mbatata Roots and Tubers Association (CMRTE), Domasi, Malawi
Chrissie Katundu, farmer representative

Approach

Using a mix of quantitative and qualitative methods, surveys and inventories of cassava products and processing technologies were undertaken to provide key details on the role of cassava. Specifically, national agricultural survey data and integrated household survey data focusing on cassava production and utilisation provided the quantitative data for analysis. Qualitative key-informant interviews with 272 value chain participants, such as farmers, traders and consumers, were conducted to gain insights into cassava marketing and cassava safety dynamics. The interviews provided information on the key products and technologies to be tested based on the regional value chain studies and food safety evaluations of cassava products in Malawi, Mozambique and Zambia.

The research also addressed the question of how and where in the value chain are women and men participating, as cassava is increasingly commercialized. Focus group discussions and in-depth

interviews were carried out in Malawi, Mozambique and Zambia with actors actively engaged in cassava production, processing, marketing and consumption. To get deeper understanding of the case studies, life history interviews were conducted with three women. One of the main partners in the research team was a journalist that conducted the interviews in Malawi, Mozambique and Zambia.

In addition, four MSc degree students conducted their thesis work on various aspects of cassava:

- Ghana. Nine improved and local cassava varieties were characterized for their proximate composition, mineral content and cyanogenic glycoside potential using standard analytical methods.
- Malawi. The project, which previously was executed by IITA from 2008 to 2010, aimed to assist farmers to increase food security and improve livelihoods through promoting cassava cultivation. In this study, 120 beneficiary households of the IITA project "Unleashing th Power of Cassava in Africa" project in Kasungu and Dowa provinces in Malawi were interviewed using a semi-structured questionnaire together with key informant interviews and focus group discussions.
- Zambia. In this project the focus was on identifying the various physical and rheological properties of cassava varieties. By mapping out the various chemical properties for a specific variety we can test products and test consumer acceptability. It is in matching these qualities that we can attain food safety and quality for the actors along the cassava value chain. The chemical composition of cassava depends on the specific tissue (root or leaf) and on several factors, such as geographic location, variety, age of the plant, and environmental conditions. Knowing the characteristics of the varieties is essential when developing the right products with the right end-user preference.

Finally, through senior scientist exchange visits, researchers involved in the collaboration participated in, and conducted, workshops in Malawi, Zambia, Uganda and Mozambique. These workshops comprised:

- Inception research project programme (Host: Dr Drinah Banda Nyirenda, University of Zambia).
- Cassava varietal understanding with farmers [Host: Mrs Chrissie Katundu, Chinangwandi Mbatata Roots and Tubers Association (CMRTE, Malawi)]
- Cassava transformation in Southeastern Africa (CATISA) [Host: Dr Yona Baguma, National Agricultural Research Organisation (NARO) Uganda)]
- Fast-tracking cassava transformation in southeastern[1] Africa to improve food security and livelihoods [(FAST-Tracking-CATISA) (Host Dr Annabela Zacarias, Instituto de Investigação Agrária de Moçambique (IIAM), Mozambique)]

Scientific results

The results from the studies on the role of cassava show that 1) the transfer of improved cassava varieties and 2) processing technologies have affected commercial opportunities and household food security in the countries of southeastern Africa. Our research in Malawi and Zambia demonstrated that production of cassava roots with high concentrations of the toxin linamarin often could be found in regions where cassava had been newly introduced. This situation means that chemical food safety is threatened, in particular due to missing knowledge of how to process cassava. Processing of cassava roots are done for several re-

Photo: Görel Espelund

Cassava flour - produced, processed and packaged by CMRTE farmers in Malawi.

[1]Southeastern Africa refers to the geographical region including DR Congo, Malawi, Mozambique, Tanzania and Zambia defined by the cross-border staple crop trading. In CATISA- the nucleus countries for understanding the cassava commercialization processes include: Malawi, Mozambique and Zambia.

Photo: Görrel Espleund

At the Kanakantapa Women's Cassava Project, outside Lusaka, Zambia

asons: 1) to prepare healthy delicious meals; 2) in order to obtain stable intermediate products from the otherwise perishable roots and, 3), to reduce the content of the toxin linamarin.

Using data from the surveys and secondary sources from the agricultural statistics we found that the bitter varieties, though high in potentially toxic cyanogenic glycosides, typically predominate because of their high yield, multiple-year in-ground storage potential and disincentives against theft. Even though they require greater care in processing, bitter varieties account for the bulk of regional cassava production. Sweet varieties, lower in cyanogens, and mostly consumed fresh, account for a smaller proportion of cassava grown. Using non-marketed volumes as a rough proxy for bitter cassava production suggests that bitter varieties account for about 80-90% of national cassava production in Mozambique and Zambia and 70-80% in Malawi. Given growing popularity of fresh cassava as an urban snack food, the proportion of sweet varieties in total production appears to be rising over time in Malawi.

Results from research on how women involved with cassava are affected by commercialization.

We found that in order for more women to raise their labour productivity and earnings, several key public goods are required: a) breeding of higher yielding, long storing and disease resistant varieties (for the same labour, the women harvest more); b) simple mechanisation of peeling and processing to reduce drudgery; c) scientific study of key fermentations to identify ways of improving product safety, quality and shelf life (inoculations may work in some situations); d) product development and packaging that raise added value as well as the value of final products women sell.

Results from the master's thesis carried out in Ghana.

The results of the chemical analyses showed wide variations in visco-elasticity properties and pasting properties. Similarly, variations in swelling power, solubility and water binding capacity were also noted. Among the studied varieties there was one variety, "Sika" that had exceptionally high viscoelastic properties. These characteristics could be used in their selection for specific food and industrial processing applications. Regarding the improved varieties, wide variations exist in chemi-

cal composition of the improved and traditional cassava cultivars but all contained safe levels of cyanogenic glucosides and were deemed safe for human consumption.

Results from the master's thesis research in Malawi. The research on the promotion of cassava cultivation revealed that despite issues regarding quality and timeliness of the seed distribution service, the majority of the beneficiary households were satisfied with the project stating that it helped improve their food security and livelihoods. However there emerged issues of exclusion of the most vulnerable households, particularly low participation of female-headed households, which were initially targeted by the project. The study concludes that future projects should be designed for the agricultural calendar to respond to timeliness, longer duration and better targeting of the beneficiaries.

Results from the master's thesis research in Zambia. The research on physical and rheological properties of cassava varieties showed that eight of the nine varieties had high dry matter content ranging from 80-90%. With the exception of "Manyokola" and "Nalumino", which had low HCN equivalents per kg dry weight (5.39 and 6.70 respectively), the remaining seven varieties had high cyanogenic glucoside levels classifying them as bitter. The results also showed that some of the varieties had excellent pasting properties. The findings provide a foundation for more detailed work on varietal end-use applications.

The concerted findings will contribute towards enhancing cassava commercialisation along the value chain for various end-users. In particular the forthcoming paper on exploring cassava trajectories is aimed at revisiting wider policy issues on staple crops in Southern Africa.

Dissemination of results

Throughout the execution of this project great effort has been made to communicate the findings with the wider society and to generate informed debate. Our findings have been published on the following debate forums: biståndsdebatt, Omvärld and Värmlands Folkblad. In Zambia, the research team had an audience with President Rupiya Banda in April 2012 to discuss the role of cassava as a food security crop but also a crop with commercial possibilities. Hitherto, three articles have been published in peer-reviewed journals. Three of the four workshops listed in the approach section were held and hosted by the local agricultural university or research institute in each of the three focus countries, Malawi, Mozambique or Zambia where presentations and discussions were held to further the understanding and direction of the research. In 2012, the team was part of the organizing committee of the Global Cassava Partnership Conference in Uganda where ten papers and three posters were presented by members of the team. Particular effort was made to include the end-users, and farmer organisations were therefore included in the team and in dissemination of the information. In the final quarter of the research grant, four simple solar driers commonly used in Ghana were locally constructed by the University of Zambia as a result of these South-North university relations in food science.

Photo: Görrel Espeund

Value added products - cassava leaves by Sylva Foods in Zambia.

"The scientific networks for female scientists at institutions of higher learning have been strengthened"

Photo: Görrel Espelund

Mozambique women painstakenly manually breaking the fermented cassava mash rale.

Gender aspects

Gender aspects have been taken into consideration both when it comes to the actual research (see the study addressing how women in cassava are affected by commercialisation) and in selection of team members. Both the principle investigator at SLU and the co-principle investigator at the University of Zambia and IIAM are women. Specifically, the scientific networks for female scientists at institutions of higher learning have been strengthened, and there have also been opportunities for new proposal writing constellations. Among the key partners in the collaboration team is the farmers group CMRTE, of whose members more than 85% are women. Furthermore, the NGO partner in Zambia, "Programme Against Malnutrition" is also lead by a woman. Seven of in total twelve scientists from the twelve institutions actively participating in the team were women. Two MSc students were women and two were men.

Greatest value of the program

The greatest value of the program is that it has consolidated the (CATISA) consortium, which has had the possibility to chart a more defined course for future research questions. The team is poised to undertake capacity building activities highlighting cassava food safety, product development, the relevance of training and conducting interdisciplinary research for deeper understanding in fast-tracking cassava in Southeastern Africa. Not only did the programme provide the means to carry out the activities, but the project period also enabled the team to further cement their working relationships on a longer term basis. New research applications from other sources of funding have been submitted to potential donors. Most of all, interacting and communicating with a wide range of actors in Africa, Europe and USA has been invaluable.

A summary of the statistics for this project on p.171

Watermelons, Zimbabwe

Photo: Claid Mujaju

8. Plant breeding and genetic resources – collaborations between SLU, South Africa and southern Africa

Plant breeding and genetic resources – Collaborations between SLU, South Africa and southern Africa

Project leader: Eva Johansson

Summary in Swedish

Växtförädling och genetiska resurser – samarbeten mellan SLU, Sydafrika och södra Afrika

Syftet med detta projekt var att öka samarbetet mellan Sverige, Syd- och södra Afrika genom gemensam utbildning på doktorand och mastersnivå och genom studentutbyte på masters-, doktor- och post-doktorsnivå. Fokus inom projektet har varit inom ämnesområdet växtförädling för ökad avkastning, livsmedelskvalitet och livsmedelssäkerhet. De grödor som prioriterats inom projektet har varit framför allt vete och sorghum men har även inkluderat vattenmelon och vindruvor. Projektet som helhet har varit ett viktigt bidrag till en doktorsavhandling, genererade två mastersstudenter, en honoursstudent och en gemensam doktorandkurs. Vidare har projektet genererat vetenskapliga publikationer och fortsatt samarbete bland annat genom en gemensam doktorand. Frågeställningarna inom projektet handlade bland annat om variationer i bakningskvalitet och nutritionella faktorer i sydafrikanskt brödvete, genetisk variation samt variationer i kvalitet för pastatillverkning av durumvete, kvalitetsvariationer i sorghum, samt preferenser gällande vattenmeloner. I ett delprojekt undersöktes och jämfördes den genetiska sammansättningen av viktiga grödor med särskilt fokus på vindruvor och sorghum. Detta projekt syftade dessutom till att stärka kunskapen och infrastrukturen kring bioinformatisk analys, ett outvecklat område inom jordbruksforskning i södra Afrika. Här summeras kort några av de resultat som framkommit inom projektet. Mängden antioxidanter i vete korrelerade generellt negativt med vetets brödbakningskvalitet. Det fanns emellertid vetesorter som innehöll både höga halter av tex tokoferoler och som hade bra brödbakningskvalitet; ett exempel på en sådan vetesort var sorten Caledon. Mängden tokoferol var högre i fullkornsmjöl än i vitt mjöl. Sorghumsorter utvärderades med avseende på avkastning, proteininnehåll och innehåll av mikronäringsämnen. Resultaten visade att det fanns en stor genetisk variation för de olika undersökta parametrarna. Vidare visade resultaten på stora möjligheter till samtidig förädling för bättre egenskaper i flera av de undersökta parametrarna. För undersökning av genetiska resurser gällande sekvenserade växtgenom, konstruerades ett nytt bioinformatiskt arbetsschema och med hjälp av en superdator byggdes ett ”gen-nätverk” baserat på likheter i DNA-sekvenser mellan 26 växtarter. Resultaten gav en delvis ny bild av genetiska likheter och skillnader mellan viktiga grödor och kan användas för att identifiera gener och genfamiljer med viktiga egenskaper i framtida växtförädling. Doktorandkursen ”Fieldomics” avhölls inom projektet med studenter från de inblandade länderna. Projektet som helhet har lett till ökad samverkan som fortfarande är pågående, kapacitetsuppbyggnad i form av studenter som har avlagt examina på olika nivåer, ett ganska stort antal vetenskapliga publikationer som är under utarbetande samt spridning av resultaten både till vetenskapssamhället och till brukare av resultaten såsom odlare, växtförädlare och genbanker.

Summary

The aim of the present project was to increase cooperation among Sweden, South and southern Africa through joint education on the PhD and MSc level and exchange students at the MSc, PhD and Post-doc level. The focus subject was plant breeding for increased yield, food quality and food safety and security. Priority crops within the project were wheat and sorghum, but also crops such as watermelon and grapes (viticulture) were incorporated as subprojects. The project as a whole has contributed to the generation of one PhD-thesis, has generated two MSc-students, one Honours student and one joint PhD-course. An expected number of ten manuscripts are likely to come out of this project. Furthermore, continued collaboration is expected by a joint PhD-student. The questions within the project has mainly dealt with variation in bread-making quality and nutritional factors in South African bread wheats, genetic variation and variation in quality in durum wheat for pasta production, quality variations in sorghum as well as preferences of water melons. A summary of some of the results showed that the content of antioxidants correlated negatively with most baking characteristics in wheat. However, some exceptions were found; the cultivar Caledon had good quality characteristics for both tocopherols and baking quality. Highest content of tocopherols were found in whole meal as compared to white flour. Sorghum lines were evaluated for grain yield, protein and micronutrients content. The results showed a significant genetic variation among sorghum

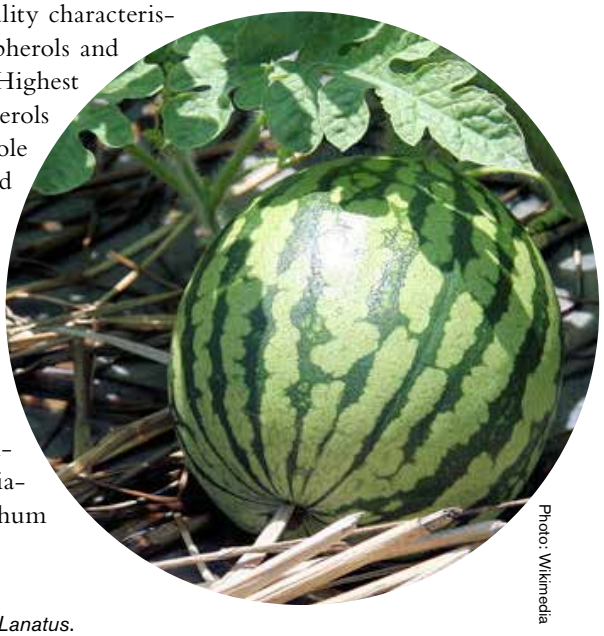


Photo: Wikimedia

Watermelon *Citrullus Lanatus*.

lines, and positive correlation among the traits indicated possibility of improvements for more than one trait. For comparison of genetic resources of sequenced plant genomes, a new bioinformatics workflow was constructed and with the help of a high-performance computer a cross-species gene network was built based on sequence similarities between 26 plant species. The results gave new insights in genetic similarities and differences between important crops and can be used to identify genes and gene families with important characteristics for future plant breeding. The PhD-course Fieldomics was successfully carried out with students from involved countries The project as a whole has led to an increased collaboration (which is still ongoing), capacity building in terms of students that have graduated on various levels, a relatively large number of papers in international peer review journals, several of them still under production, and spreading of the results to both the scientific society and to users in terms of farmers, plant breeders and gene banks.

Background

The present project was established due to a long-term collaboration between Prof Eva Johansson at SLU, Sweden and Prof Maryke Labuschagne at the University of the Free State in South Africa. The University of the Free State has since long had the only Department of Plant Breeding (now Crop Science) in Africa and thus the longest tradition in Africa as to education, doctoral training and research in plant breeding. Maryke Labuschagne, is strongly devoted to plant breeding research of crops for Africa with long experience of training Masters and PhD-students from South and southern Africa. Furthermore, Dr Eric Alexandersson carried out his post-doc period at Stellenbosch University, South Africa, so even between SLU and Stellenbosch University, a collaboration was already established. Three other institutions have been involved in this project; Zambia Agriculture Research Institute, National Plant Genetic Resources Centre, Chilanga, Zambia, Seed Services, Department of Research and Specialist Services, Harare, Zimbabwe and Wollo University, Ethiopia. The planning of the project was to also connect various institutions in Africa carrying out plant breeding activities to each other.

The aim of the project was to; increase cooperation among Sweden, South and southern Africa within the research area of plant breeding for increased yield, food quality and food safety and security.

Collaborations

SLU
Eva Johansson (project leader), Helena Persson Hovmalm, Staffan Andersson, Maria Luisa Prieto-Linde, Emma Jönsson (MSc student) – Dept. of Plant Breeding
Erik Alexandersson – Dept. of Plant Protection Biology

University of the Free State, South Africa
Maryke Labuschagne, Angeline van Bijon, Nocembo Mkhatywa (MSc student)

Stellenbosch University, South Africa
Dan Jacobson, Melane Vivier, Armin Geiger (MSc student), Deborrah Weighill (Honours student)

Wollo University, Ethiopia
Faris Hailu (PhD student, partly at SLU)

Zambia Agricultural Research Institute, Zambia
Dickson Nguni

Seed Services, Harare, Zimbabwe
Claid Mujaju

Approach

Students for exchange and other relevant exchange activities (meetings with researchers involved, stakeholders and joint PhD-courses) were discussed and jointly planned. Furthermore materials and methods to be used by students were similarly planned and discussed jointly. Plant material was grown for the project, primarily in South Africa on plant breeding companies and on research farms. Thereafter the plant material was analyzed with conventional methods on lab including HPLC analyses for antioxidant and protein composition and contents. As for the bioinformatics studies to evaluate genetic resources, computers and models were used in order to evaluate the material using network theory combined with multivariate data analyses method development. By the use of such programs, RNA editing and parallelization of OrthoMCL and network-based annotation and contextualization can be carried out. In general the projects were divided into eight different sub-projects as follows;

1. Quality in South African bread wheat - protein composition, antioxidant composition (tocophe-

rols) and bread-making quality was evaluated in a set of breeding lines over two years.

2. Quality in durum wheat – field evaluation for genetic variation and evaluation of protein composition was evaluated in an Ethiopian durum wheat breeding material over two years.

3. Quality in South African sorghum lines – Quality evaluations and protein composition analyzes was carried out in a South African material of sorghum breeding lines over two years.

4. Quality in Zambian sorghum lines – Quality evaluations were carried out in a Zambian sorghum breeding material over one year but grown in South Africa and Zambia.

5. Evaluation of preferences for Zimbabwian water melon lines – a study was carried out to evaluate preferences on water melon lines in Zimbabwe.

6. Identification and systematization of genetic resources by the establishment of a new bioinformatical workflow and use of a high-performance computer.

7. Identifying RNA-editing sites in crop species for analysis of their putative influence on crop performance.

8. Development of a joint PhD-course in Fieldomics.

Scientific results

Opportunities to combine nutritional and baking quality in South African wheats were investigated. The results showed that the content of antioxidants, known being associated with nutritional quality and health aspects, correlated negatively with most baking quality characteristics. However, some exceptions were found, the cultivar Caledon had good quality characteristics for both tocopherols and baking quality. Highest content of tocopherols were found in whole wheat meal as compared to white flour.

Content of tocopherols in South African wheats and variation over years, location and wheat genotypes was investigated. A large variation for both tocopherols and tocotrienols were found in the material and due to environmental conditions. Selection of wheats based on tocotrienols content is important due to the high relative contribution of wheats for tocotrienols in the human diet.

Sorghum lines were evaluated for grain yield, grain protein content and grain micronutrients content. The results showed a significant genetic variation between the sorghum lines, and positive correlation among the traits indicated possibility of improvements for more than one trait.

A comparison was made of genetic resources using sequenced plant genomes by constructing gene family networks across 26 plant species using customized computer scripts. The networks were used to identify correlations between species based on gene family content as well as putative homologs, and thus identified enriched and shared function between crop plants in an efficient way. These gene networks are a future resource to functionally annotate and identify genes and gene families important in plant breeding and crop performance. Furthermore, putative new RNA-editing sites were identified in the model plant *Arabidopsis thaliana* by comparing transcriptome and protein data.

Dissemination of results

In South Africa, the plant breeding industry is relatively well developed with a number of plant breeding companies working on the market with the development of new cultivars of wheat and other crops to be distributed to the South African farmers and growers. The plant breeding unit at the Department of Crop Science at University of the Free State in South Africa, generally has strong collaboration with the plant breeding companies that has been long-lasting. Especially the ARC-Small Grain Institute (ARC-SGI), Bethlehem, Eastern Free State, is a strong collaborator in many of their projects. In the present project, contacts have been taken with several of the plant breeding companies and plant material has been received from two of them for evaluation of the quality characteristics. All involved students visited the ARC-SGI, and meetings were held with plant breeding companies in South Africa. Also for the evaluation of the sorghum material, breeding materials from the South African plant breeding of improved varieties were used together with lines from the SADEC gene bank that were grown at the ARC-SGI in South Africa. As the South African plant breeding companies and institutes have been largely involved in the project, the companies expect feed-back in terms of immediate update on the results which they also got.

The post-docs involved in the project are both employed by the Zambian gene bank and Seed

"The scientific results contribute to plant breeding efforts for higher yield and better quality of important crops, thereby contributing to food security in this region of Africa"

Photo: Claid Mujaju

Selling watermelons along the road to Chiredzi in Zaka, Zimbabwe.

service institute meaning that they have direct contact with breeders and farmers in their respective countries leading to direct transfer of results. The PhD-student, Faris Hailu, who finalized his thesis work within the project, has a position as a teacher at Wollo University in Ethiopia and is also the main responsible person for student recruitment and acceptance to programmes/courses in natural/agricultural science. This means that the knowledge from this part of the project will be directly transferred to students at the university.
All results from the project are also on its way to be scientifically published. Two scientific papers from the project have until now been submitted while additional six are in manuscript form, planned to be finalize and submitted during 2013.

Gender aspects

In this project a total of six senior staff were involved, of which three were female. A total of seven students were involved, four male and three female. The staff being responsible for lab experiments was all female. Thus, the gender balance among involved persons in the project has been relatively equal.

Thus, the gender balance in these projects was equal in terms of who did what work. However, also, gender-related ideas and opinions of involved persons play an important role. The project management was attentive to these issues and contributed to keep them active.

Greatest value of the project

The project has contributed to capacity building in South Africa, southern Africa (Zambia and Zimbabwe) and Ethiopia. Furthermore, the project has contributed to increased collaboration within Africa between countries and research environments. The project has also contributed to increased collaborations between SLU and research environments in South Africa, southern Africa and Ethiopia. Finally, the project has contributed to new science-based knowledge on local crop varieties from the South/southern part of Africa. The scientific results contribute to plant breeding efforts for higher yield and better quality of important crops, thereby contributing to food security in this region of Africa.

A summary of the statistics for this project on p.173

9. Biological crop protection systems in southern Africa

Panorama of the visit to the Fynbos at Jonkershoek outside Stellenbosch.
Photo: Pernilla Borgström

Photo: Pernilla Borgström

Visit to Fynbos, Jonkershoek outside of Stellenbosch. Professor Jan Bengtsson (SLU) describes the vegetation.

Synthesis

The 21st century is faced with a colossal challenge of increasing agricultural production, whilst simultaneously decreasing the impact human agricultural production has on the environment. This demands creative and novel 'green' and 'sustainable' production systems, which are increasingly researched in Europe. However, such novel cropping systems sorely need attention in African agro-ecosystems which, due to steep population growth, may be under the strongest pressure to meet this challenge. With regard to the choice of region, southern Africa is a key region of interest for driving innovation. As one of the most developed countries in Africa, South Africa is a focal point for foreign investments and acts as a hub for intra-African research and development. In that light, efforts that include southern Africa seem appropriate.

A crucial factor in creating momentum is generating awareness, through capacity building and collaboration, and through technology transfer. Accordingly, a large share of our efforts have been put into researcher exchange at all levels (i.e. from undergraduate to professor) and across research institutes and universities in southern Africa, eastern Africa and Sweden. Two collaborative visits, a PhD course, a pan-African conference, and a field workshop highlight this. The strengthened collaboration and crosstalk between the various groups has been pivotal for building a scaffold for multidisciplinary integrative, rather than fragmentary, research across groups.

Occasional successes have been and are being scored in research on sustainable cropping methods. Such local successes in sustainable crop production can create momentum for spread of new research and implementation of new principles. The latter, however, need mechanisms of support. This project has provided such a tool for the spread of research methods and principles on East African push-pull management systems in crops other than the maize-stem borer system for which it was originally developed. It supported the long-term researcher exchange and collaboration between East Africa, southern Africa, and Sweden for research on development and implementation of a push-pull sustainable management system in sugarcane in South Africa. This provides opportunities, particularly for smallholder farmers for simultaneously increasing production and decreasing environmental impact in agro-ecosystems.

The project "Biological crop protection systems in southern Africa" has thus provided pivotal input in the areas of capacity building, technology transfer and research initiatives in the area of agro-ecosystem services and pest control. Although already successful by itself, ripple effects will be felt in years to come through the from the increased cross-talk across research groups working on similar issues, with a diverse set of focuses, approaches, and tools.

Teun Dekker (coordinator)

Chemical ecology in integrated control of insect pests in southern Africa

Project leader: Teun Dekker

Summary in Swedish

Kemisk ekologi inom integrerat växtskydd mot skadeinsekter i södra Afrika

En snabbt växande afrikansk befolkning kräver ökat fokus på livsmedelssäkerhet, samtidigt som klimatförändring och skadegörare utgör hot mot redan ansträngda jordbruksekosystem. Det finns därför ett stort behov av nya ekosystembaserade växtskyddsmetoder som ökar jordbruksproduktionen både på kort och lång sikt. Det här projektet har möjliggjort uppbyggnad av två växtskyddsinriktade samarbetsprojekt. I det ena projektet, med fokus på en invasiv fruktskadegörare, *Bactrocera invadens* (African invasive fruit fly), utgör studier av grundläggande och kemisk ekologi basen för utveckling av metoder för att begränsa förekomsten av denna skadegörare. Det andra projektet handlar om utveckling av en kemisk ekologisk metod, så kallad "push-pull", för att begränsa skador orsakade av larver av *Eldana saccharina* (sugarcane borer) i sockerrörsodlingar. Metoden bygger på samodling där de växter man kombinerar med grödan avger dofter som verkar avskräckande på skadeinsekter och/eller attraherar naturliga fiender. Projektet har också bidragit till att arrangera en workshop "Chemical Ecology in Multilevel Pest Management, SEMIO-11", som hölls i november 2011 i Nairobi. Mötet utgjorde ett tillfälle för kapacitetsutveckling och nätverkande för afrikanska forskare och studenter med intresse för kemisk ekologi. Vidare har projektet möjliggjort för en kvinnlig kenyansk doktorand att studera i Sydafrika (kemisk ekologisk bekämpning av skadegörare på sockerrör) samt stöttat en svensk postdok att genom deltagande forskning, som bygger på att bönderna engageras i forskningsprocessen, hitta metoder för att begränsa skador av *Bactrocera invadens* i fruktodling. Projekten har bedrivits i Sydafrika i samarbete med Etiopien och Kenya.

Summary

A rapidly increasing African population poses serious food security threats and places additional strains on agro-ecosystems that are already under stress. Innovative crop protection methods that foster ecosystem services and, at the same time, increase agricultural productivity in the short and long term, are therefore much needed. In this context the project - "Chemical ecology in integrated control of insect pests in southern Africa" - has provided capacity and research links for initiation of two research projects. Furthermore, the project supported research on sustainable push-pull control of the sugarcane borer, *Eldana saccharina* in sugarcane. Different from in its native habitat (sedge vegetation), *E. saccharina* defies biological control in sugarcane. The cause behind this, although still under investigation, seems primarily to be caused by inadequate recognition by parasitoids of sugarcane that is under *E. saccharina* attack. Research on how to remediate the situation, using smart intercropping, is ongoing.

During this project we also arranged an important networking and capacity development activity with many African researchers; the workshop "Chemical ecology in multilevel pest management, SEMIO-11". In addition, the project has supported an East African PhD student for her PhD studies in South Africa, as well as a Swedish postdoc for participatory research projects on the African invasive fruit fly. Focal countries for research have been South Africa, in collaboration with Ethiopia, Kenya.

Background

South Africa is important in regional development of Africa. Not only does it attract foreign investments, it also has the advantages of infrastructure, and education levels across the population. As a hub for economic development in Africa, South Africa may be an important route for stimulating innovation in African agro-ecosystems, both through education and research.

However, South Africa has a mix of both smallholder farming and large-scale farming, where most

Damage of *Eldana saccharina*

Photo: Des Colong

efforts on pest control have been focusing on large-scale farming. Therefore, research on the control of pests in smallholder farming would benefit from collaboration on research and expertise exchange with other parts of Africa.

Through SEMIO-08, a predecessor of SEMIO-11, we noted the importance of (financial) incentives and platforms for researchers across Africa. One of the aims of this project was to create synergy within research, capacity development, and networking, through collaborations in South and East Africa, focusing on research on push-pull systems.

Collaborators

SLU

Teun Dekker (project leader), Miriam Karlsson, Ylva Hillbur – Dept. of Plant Protection Biology

University of Kwazulu Natal, South Africa
Andreas Juergens

SASRI (South African Sugar Cane Research Institute), Durban, South Africa
Des Conlong, Stuart Rutherford

icipe (International Center of Insect Physiology and Ecology), Nairobi, Kenya

Paul-André Calatayud, Sunday Ekesi, Carolyn Okoth (PhD student), curently at SASRI

Approach

A cropping system has been developed in East Africa which integrates insect pest control into a larger scheme of fertilization, control of parasitic weeds, diversification of cropping systems, and animal fodder production. The system, coined push-pull, utilizes the synergistic benefits that intercrops provide in pest control. It was developed to control the maize stem borer, and is based on a series of discoveries including a preference of the borer for plants that do not support development of offspring but provide good fodder for dairy (napier grass), whereas other crops such as *Desmodium*, are repellent for the maize borer, beneficial for nitrogen fixation and important in control of the parasitic weed *Striga*. Through smart intercropping with crops, as the ones listed above, important yield benefits can be achieved. In this project, the experiences gained from the development of the push-pull system was used to adapt the system for use in farming of sugarcane, a crop important in both large-scale and smallholder farming in Southern Africa. For this, classical chemical ecological methods are combined with field knowledge of the pest ecology in South Africa. As a first step, different varieties of sugarcane (SASRI has 150 different varieties) under herbivore attack were tested on their ability to induce host searching in two parasitoid species. Semio-chemical profiles of varieties inducing and not inducing host searching are subsequently compared to identify cues that may act as attractant for parasitoids and repellent for herbivores. Such baits and repellents can be employed in push-pull settings. The research is ongoing with a PhD student trained in Kenya on push-pull systems, and placed in South Africa to work on sugarcane push-pull.

Scientific results

Smallholder farmers in southern Africa increasingly use sugarcane as a cash crop. Our research concentrates on the chemical ecology of the su-

Photo: Des Colong

The sugarcane borer *Eldana saccharina*.

garcane borer *Eldana saccharina*, a serious pest in sugarcane. The pest goes unchecked, however, as *Cotesia* parasitoids, which parasitizes *E. saccharina* in surrounding native vegetation; seemingly do not recognize the pest inside sugarcane, although effectively parasitizing *E. saccharina* in surrounding vegetation. The system shares several characteristics with the well-studied maize borer (*Chilo partellus*) push-pull model. Whereas research is still ongoing, possible avenues for future sustainable intervention have been identified which include intercropping with native hosts (sedge, to pull pest out of sugarcane), intercropping with hosts that pull in parasitoids into sugarcane fields, and particularly use of attractive odor baits to pull or push herbivore and/or natural enemy out/in the crop. Considering the expertise present in Kenya with the push-pull system, we recruited a former icipe MSc student for this position. We also link our research directly to ongoing research in Kenya (collaboration with Dr Paul Calatayud). This project therefore supports intra-African excellence and capacity developing networks.

The results so far demonstrate that old, more ancestral varieties of sugarcane induce significantly increased search responses in parasitoids than the high yield varieties used commercially. Two parasitoids, *Cotesia sesamia* and *Xanthopimpla stemmator* show sugarcane variety and stemborer species (*Eldana saccharina, Chilo partellus*, and *Sesamia calamistis*) dependent attraction to herbivore cues. Invariably the ancestral sugarcane variety induced better parasitoid performance. Further experiments will examine the difference in chemosensory cues that underlie this difference in parasitoid behavior. Furthermore, ongoing experiments with stemborers examine the importance of these cues in oviposition choice by females. The thought is to use identified cues in future push-pull strategies.

Dissemination of results

This project provided the incentive to SEMIO-11, a pan-African workshop on chemical ecology in multilevel management. Seventysix researchers from 16 nations participated. Through the project we could support participation in the workshop for 29 delegates from 11 African nations. Furthermore, the project will, through SASRI, support the dissemination of research on push-pull in sugarcane to both large-scale and smallholder farmers.

Gender aspects

Our recruitment, research exchange and publication strategies have favored the representation of women. Women are disproportionally engaged in high value cropping systems and sales. Programs that support these activities therefore favor economic growth, educational opportunities and health care of women and children.

Greatest value of the program

1. Supporting a large pan-African workshop, SEMIO-11, on chemical ecology and multilevel management.
2. Training of one PhD student, and one postdoc in innovative control of insect pests.
3. Interlinking East Africa and southern Africa in research on push-pull and utilizing experiences from the maize stem borer in other cropping systems.

Photo: Des Colong

Hole of an *Eldana saccharina* larvae, boring into sugarcane.

A summary of the statistics for this project on p.174

"The project will, through South African Sugarcane Research Institute (SASRI), support the dissemination of research on push-pull in sugarcane to both large-scale and smallholder farmers"

Biodiversity and ecosystem services: interaction and utility

Project leader: Barbara Ekbom

Summary in Swedish

Biologisk mångfald och ekosystemtjänster: interaktion och nytta

En mycket viktig fråga för framtiden är hur man kombinerar målet att skydda biologisk mångfald med målet att öka produktionen i jord- och skogsbruk. En stor utmaning för att utforma odlingssystem som bidrar till tryggare livsmedelsförsörjning är att förstå hur ekosystem och organismer inom dessa kommer att påverkas av klimatförändring, förändrad markanvändning, och invasion av främmande arter. Inom detta projekt har vi lagt grunden till ett fördjupat samarbete mellan svenska och sydafrikanska forskare samt gjort det möjligt för doktorander från Sverige och Sydafrika att interagera. Projektet engagerade forskargrupper vid SLU och universiteten i Stellenbosch, Pretoria och Free State i Sydafrika. I mars 2012 träffades forskare från Sverige och Sydafrika i Stellenbosch för att diskutera gemensamma framtidsprojekt samt planera en doktorandkurs. Doktorandkursen ägde rum i Sydafrika i november-december 2012. Åtta doktorander från Sydafrika och åtta från Sverige deltog i kursen som bland annat innehöll fältstudier där studenterna undersökte möjligheten att utveckla odlingssystem där biologisk bekämpning spelar en stor roll för växtskydd av grödor. Betydelsen av ekosystemtjänster för tryggare livsmedelsförsörjning behandlades i föreläsningar och studentprojekt.

I samband med en årlig konferens om trädhälsa i maj 2012 besökte tio svenska forskare och doktorander The Forestry and Agricultural Biotechnology Institute (FABI) i Pretoria. Trädhälsa är en viktig del av utvecklingen av odlingssystem där man samodlar träd och ettåriga grödor. Under fältbesök studerades utveckling av biologisk bekämpning för att minska skador från insekter och svampsjukdomar. En workshop som behandlade problem med invasiva arter och deras potentiella hot mot framtida produktionssystem, engagerade tio doktorander och femton forskare från Sydafrika och Sverige. Aktiviteterna har öppnat för nya möjligheter till samarbete mellan etablerade forskare och morgondagens forskare.

Summary

A very important question for the future is how to combine the objective of protecting biodiversity with the goal of increasing production in agriculture and forestry to increase food security. A major challenge for designing cropping systems for food security is to understand how ecosystems and organisms will be affected by climate change, changing land use, and invasive alien species. Within this project we have enabled a deeper cooperation between Swedish and South African scientists and made it possible for students from Sweden and South Africa to meet and interact. The project included research groups at SLU and the Universities of Stellenbosch, Pretoria and Free State in South Africa. In March 2012, scientists from Sweden and South Africa met in Stellenbosch to discuss future projects and plan a PhD course that was held in South Africa in November-December 2012. Eight students from South Africa and eight from Sweden participated. The course included field studies that showed students the prospects of designing cropping systems where biological control plays a major role in protecting crops. Projects that investigated the importance of biodiversity for ecosystem services were also carried out. In conjunction with an annual tree health conference in Pretoria ten Swedish researchers and graduate students visited The Forestry and Agricultural Biotechnology Institute (FABI) in Pretoria in May 2012. Tree health is important in designing agroforestry cropping systems for food security. During visits to production facilities and infested forest areas participants discussed research on biological control for reducing the impact of pests and pathogens. A workshop concerning invasive organisms and their threat to future production involved about ten PhD students and fifteen researchers from South Africa and Sweden.

The activities have opened up new opportunities for cooperation between both established scientists and tomorrow's scientists.

Background

Food security will be benefited by the active encouragement of

Visit to a commercial orchard to talk about biological control of insect pests.

Photo: Jörg Stephan

ecosystem services. Ecosystem services are the benefits people obtain from ecosystems. Biological control and soil health are examples of services provided by organisms such as plants and insects. Biodiversity conservation is therefore important for the safe delivery and stability of services such as food production. The relationship between biodiversity and ecosystem services is important to understand in order to develop appropriate and successful adaptive management in production systems. Organisms both above and below the ground can be used to study how food web structure influences ecosystem processes, both in theory and in an applied context. This has led to an interest in the importance of biodiversity for ecosystem functioning, and management of landscapes for sustainable cropping systems and biodiversity conservation.

Collaborators

SLU

Barbara Ekbom (project leader), Jan Bengtsson – Dept. of Ecology
Jan Stenlid – Dept. of Forest Mycology and Plant Pathology
Birgitta Rämert – Dept. of Plant Protection Biology
Paul Kardol – Dept. of Forest Ecology and Management

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University of the Free State, Bloemfontein, Republic of South Africa
Schalk Louw, Wijnand J. Swart – Dept. of Zoology and Entomology and Dept. of Plant Sciences

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Des Conlong

Lund University
Klaus Birkhofer – Dept. of Biology

The Forestry and Agricultural Biotechnology Institute (FABI), University of Pretoria, Republic of South Africa
Mike Wingfield, Bernard Slippers, Jolanda Roux, Jeff Garnas, Brett Hurley

Approach

The project was built on existing scientific collaborations between SLU and two universities in South Africa – University of Stellenbosch and University of Pretoria. We brought together scientists and students from Sweden and South Africa by organizing workshops, participating in conferences as well as arranging and carrying out a PhD course. One workshop and the PhD course took place in and around Stellenbosch and one workshop and conference/workshop participation took place in and around Pretoria. The idea was to get active Swedish scientists and students to meet and exchange ideas with South African counterparts. Visits included not only presentations of scientific work but also field studies where experiments could be seen and discussed. Participants from three of SLU's four faculties were involved.

Scientific results

Collaboration with University of Pretoria

In May 2012 a group of ten scientists and PhD students from SLU visited the Forest and Agricultural Biotechnology Institute (FABI) of the University of Pretoria. The aim was to exchange knowledge and ideas, learn more about agroforestry and related problems with diseases and insect pests and initiate future collaboration. The objective of FABI is to conduct research based on new technologies, such as biotechnology, genomics and bioinformatics, together with and for the forest and agricultural industry in South Africa. FABI is partly funded by and provides the entire forestry industry of South Africa with support in tree health, particularly concerning pests and diseases. An important part of the research at FABI is the development of bio-control agents to control outbreaks of pests and pathogens of trees and crops. The visit started with the participation in FABIs 23rd annual research symposium where the Tree Protection Co-operative Programme (TPCP) together with Centre of Excellence in Tree Health Biotechnology (CTHB) presented current projects and new findings to their stakeholders. The meeting gave a good view of the broad range of different research projects conducted at FABI. On a week-long field trip, the group visited the two largest forest companies in South Africa. Both companies have extensive breeding

programmes in order to reduce losses from diseases and pests. The plantation forests in South Africa are important both for primary production of wood, but also as components in agroforestry systems. The last two days were dedicated to a FABI-SLU workshop with the title *Invasive forest threats: Future research and management opportunities*. The workshop served as a platform to develop future research collaboration and common ideas to be developed into joint projects.

PhD course in Stellenbosch

In a series of introductory lectures by scientists representing universities in Sweden and South Africa, the PhD students learned about biological control as a method to control pests. Biological control is an important part of sustainable food production systems and for some of the students this was a first, comprehensive contact with the topic. Students presented their own PhD research projects and thus opened up for input from people with different backgrounds and areas of expertise. Field trips introduced students to ongoing studies concerning ecosystem services. For instance, examples of soil biodiversity as a driver of plant growth were discussed during a visit to the indigenous fynbos vegetation of South Africa. During visits to farms examples of both soil biodiversity as a method to enhance plant production and insect biodiversity as a method to improve biological control of pests were shown. Avoiding inputs such as commercial fertilizers and chemical pesticides are important in building sustainable production systems for food security. A number of commercial apple orchards were visited, and PhD students discussed current problems and future threats to fruit production with scientists involved in developing biological control. Projects carried out by student groups of three to four people were a chance to plan and carry out short, collaborative research projects. The projects addressed the importance of insect biodiversity for soil health and the importance of insect biodiversity among biological control agents for the control of herbivores attacking plants. Despite the time limitations, all discovered that this was a useful exercise in identifying relevant research questions, and designing studies to address them. Among the results it was shown that presence of ants could disrupt biological control and that dung beetle biodiversity was important for recycling nutrients to the soil. It was shown that biodiversity contributed to ecosystem services important to maintaining food production.

Disssemination of results

The main transfer took place as capacity development. About fifteen African PhD students were actively involved in courses and workshops where the students had a chance to interact with senior scientists from both Africa and Sweden. The presentations that took place at the workshop and course triggered lively discussions. The fact that all participants were required to report on their research meant that the science and the problems addressed were actively discussed by all. Given the fact that well over 50 individuals from Africa (and 25 from Sweden) were actively involved and that contacts were made with many others during field trips a considerable amount of scientific discussion about food security has taken place.

Gender aspects

Both men and women have been represented in approximately equal proportions among both the scientists and PhD students.

Photo: Jan Stenlid

Eucalyptus seedlings in a tree nursery at a Mondi Nursery.

"...an opportunity to establish a wide network within the field of plant pathology and entomology"

Photo: Jörg Stephan

Field work by students at the de Hoop nature reserve, looking at biodiversity of dung beetles in dung from different animals.

Greatest value of the programme

Workshop in Pretoria

Specific outcomes were an opportunity to establish a wide network within the field of plant pathology and entomology. Participants from Sweden had a chance to increase their knowledge about agroforestry in another part of the world. A chance to learn about the successful cooperation between industry and university in South Africa was particularly important. A joint application for research funds is being developed and exchanges between Swedish and South African laboratories are established as a result of the contacts established in this project.

PhD course in Stellenbosch

This course was a great way to open up channels for communication between our respective universities. Mixing formal coursework with informal events allowed us to familiarize ourselves with the topic through lectures and seminars, and then continue discussions in the evenings, in the company of colleagues from different professional backgrounds. For some of the participants, this course was the first chance they had to work and interact with scientists and students from overseas. New knowledge was gained by comparing cropping systems in different environments and we learned to approach problems in new ways. Collaborative courses like this are essential parts of any PhD education.

A summary of the statistics for this project on p.175

Wheat with non-restistant rye translocation in a Kenyan Agricultural Research Institutes (KARI) field in Kenya.
Photo: Staffan Andersson

10. Genetic resources and plant breeding – collaborations between SLU and Central Asia

Genetic resources and plant breeding – collaborations between SLU and Central Asia

Project leader: Larisa Gustavsson

Summary in Swedish

Genetiska resurser och växtförädling – samarbeten mellan SLU och Centralasien

Detta projekt har utökat och förstärkt ett tidigare etablerat samarbete mellan Sverige och Centralasien genom högre utbildning av studenter från Tajikistan och Kyrgyzstan. Projektet har haft flera delprojekt: 1) resistensförädling av vete mot skadegörare och sjukdomar, 2) växtförädling för förbättrad kvalité i vete samt 3) utvärdering och användning av genetiska resurser för växtförädling av kikärtor, äpple och korn. Huvuddelen av forskningen inom projektet har varit inriktat mot vete. Släktingar till vete kan användas som donatorer av flera egenskaper. Omkring 300 vår- och höstvetelinjer med genetiskt material från råg (*Leymus mollis* och *L. racemosus*) har undersökts för resistens mot svartrost (*Puccinia graminis*), gulrost (*Puccinia striiformis*), kornmygga (*Mayetiola destructor)* och rysk vetebladlus (*Diuraphis noxia*). Vi har identifierat flera vetelinjer som har uppvisat hög grad av resistens mot alla undersökta patogener och skadegörare. Särskilt viktigt är att vi har hittat linjer med resistens mot den mest fruktade rasen av svartrost, Ug99. Detta arbete utfördes i samarbete med International Maize and Wheat Improvement Center (CIMMYT), International Center for Agricultural Research in the Dry Areas (ICARDA), Kenyan Agricultural Research Institute (KARI) och University of Minnesota.

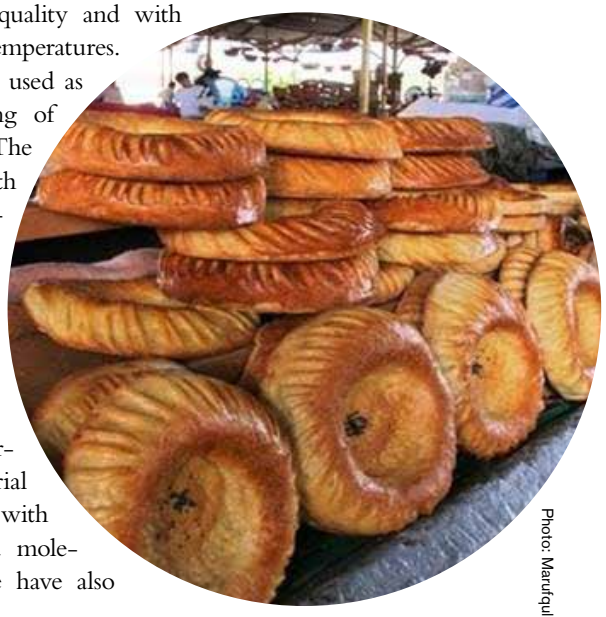
Sammansättningen och mängd av proteiner har analyserats i ett antal vetelinjer inklusive tajikiska förädlingslinjer. Växtmaterialet odlades dels under naturliga förhållanden i fält i Tajikistan och dels under kontrollerade förhållanden i biotronen i Alnarp (SLU). Vi har identifierat flera linjer som verkar lovande vad gäller bakningskvalitet och tolerans mot höga temperaturer. Dessa linjer kan användas som föräldrar i förädling av nya sorter. Samarbetet med Kyrgyzstan har mest fokuserats på kikärtor (*Cicer aretinum* L), en mycket viktig baljväxt i Kyrgyzstan pga dess höga proteininnehåll (20-30%). Den genetiska diversiteten i kyrgyziska varianter av kikärtor undersöktes med morfologiska och molekylära markörer. Vi har också med hjälp av molekylära markörer kunnat konstatera att kyrgyziska äpplen har hög grad av genetisk diversitet och potentiellt viktiga egenskaper för växtförädling. Inom projektet utvärderades även den genetiska diversiteten hos varianter av korn som odlas i Kyrgyzstan. Vi fann att det korn som man hittar i odlarnas fält i Kyrgyzstan är en blandning av flera olika sorter eller linjer.

Resultaten från detta projekt har skapat ny och viktig kunskap om genetisk diversitet hos flera grödor. Dessutom har flera lovande varianter av grödor identifierats med resistens mot skadegörare och sjukdomar och andra önskvärda egenskaper som går att utnyttja inom växtförädling. Detta projekt lade också grunden till flera nya projekt som nu fortgår.

Summary

This project has extended and strengthened a previously established cooperation between Sweden and Central Asia by education of students from Tajikistan and Kyrgyzstan. The project has the following subprojects: 1) resistance breeding of wheat against pests and diseases, 2) breeding for improved quality in wheat, 3) evaluation and utilization of genetic resources in breeding of chickpea, apple and barley. The major part of the research was focused on wheat. Wild relatives of wheat were used as donors for traits important to wheat breeding. Some 300 spring- and winter wheat lines with genetic material from rye, *Leymus mollis* and *L. racemosus* were investigated for resistance against stem rust (*Puccinia graminis*), yellow rust (*Puccinia striiformis*), Hessian fly (*Mayetiola destructor*) and the Russian wheat aphid (*Diuraphis noxia*). We have identified several wheat lines with a high level of resistance to all investigated pathogens and pests. Of particular importance is the finding of wheat lines with resistance to the widely spread Ug99 variant of stem rust. This work was performed in collaboration with CIMMYT, ICARDA, KARI and University of Minnesota.

The protein concentration and amino acid composition have been analysed in wheat lines, including breeding lines from Tajikistan. The wheat material was cultivated in Tajikistan under natural conditions and in the biotron in Alnarp under controlled conditions. We have identified several promising lines with improved baking quality and with tolerance to high temperatures. These lines can be used as parents in breeding of new varieties. The cooperation with Kyrgyzstan has focused on chickpea (*Cicer aretinum*), an important leguminous plant due to its high protein content (20-30%), where genetic diversity in Kyrgyz material was investigated with morphological and molecular markers. We have also



Tajik bread.

Photo: Marufqul Mahkamov

used molecular markers to study the genetic diversity in apples from Kyrgyzstan. We found a high level of genetic diversity and several genes important for apple breeding. In this project we also studied and evaluated the genetic diversity in Kyrgyz barley. We can conclude that there is a mixture of many varieties or lines in the farmer's fields.

This project has created new and important knowledge about the genetic diversity in different crops. In addition, several promising lines with resistance to pests and diseases, and other desirable traits have been defined and which can now be used in plant breeding. The project has also created the foundation for several new, now on-going projects.

Background

The cooperation between SLU and two partners, Tajik Agrarian University and Kyrgyz Agrarian University was established in 2007, initially funded by Sida. The cooperation has focused on education of MSc and PhD students within areas of genetic resources and plant breeding, with the aim of strengthening research that can provide increased yields and food quality, factors which are essential for achieving food security and safety. The collaboration has been strengthened by education of students and their involvement in plant breeding oriented activities in Sweden as well as in Tajikistan and Kyrgyzstan.

The major part of the research was performed on wheat (*Triticum aestivum*) which is one of the most important staple foods in the world. However, there are various biotic and abiotic factors that reduce grain yield, and which affects food security of people worldwide. Pathogens and pests can significantly affect wheat grain yield and may result in complete failure at harvest. Farmers use either insecticides and/or fungicides, or bred cultivars with relevant host plant resistance genes to control these biotic factors. Pathogens and pests are co-evolving, which leads to the occurrence of new virulent pathotypes and biotypes, capable of "breaking" resistance genes in the host plants. New sources of resistance genes are therefore needed for crop breeding to "win" this never ending race between the host plants and their co-evolving pathogens and pests. Rye (*Secale cereale*), *Leymus spp.* and other relatives to wheat have many qualities, such as resistance against different pests, diseases and positive responses to various stresses.

New and important knowledge on disease and pest resistance, knowledge about extent and structure of genetic diversity in several important crops as well as identification of promising lines to be used within practical plant breeding are important components on the way to achieve food security. Students, educated within this project, will be very important players implementing food security goals in their home countries and internationally.

Collaborators

SLU
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Hafiz Muminjanov (Lic student), Mahbubjon Rahmatov (Lic student), Marufqul Mahkamov (Lic student)

Kyrgyz Agrarian University, Kyrgyzstan
Elnura Torutaeva ("Visiting student"), Birjan Usubaliev (PhD student), Abdybek Asanaliev

CIMMYT (International Maize and Wheat Improvement Center), Mexico
David Bonnet

ICARDA (International Center for Agricultural Research in the Dry Areas), Syria
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KARI (Kenya Agricultural Research Institute), Njoro, Kenya
Ruth Wanyera

University of Minnesota, USA
Brian Steffenson, Matthew Rouse

Approach

The project involved studies on several crops like wheat, chick pea, apple and barley and different types of plant materials. Thus, in wheat cultivars, breeding lines and wheat-alien introgression lines of both spring and winter types were analysed. About 300 different lines of wheat with various translocations and substitutions were investigated for resistance to different important diseases and pests, i.e. stem rust (*Puccinia graminis*) var. Ug99, stripe rust (yellow rust) (*Puccinia striiformis)*, Hessian fly (*Mayetiola destructor*), and Russian wheat aphid (*Diuraphis noxia*). Other important traits for a good variety, competitive at in-country and international market are high end-use grain quality and tolerance to abiotic stresses. Protein concentration and composition were analysed in diverse wheat germplasm

including Tajik breeding lines with the aim to identify desirable wheat genotypes, to be used for breeding varieties with improved baking quality and tolerance to heat stress.

The collaboration with Kyrgyzstan focused mainly on chickpea (*Cicer aretinum)*, a very important legume crop in Kyrgyzstan due to the high protein content. Chick pea plant material consisted of cultivars, landraces and breeding lines from ICARDA. Collaboration on utilization of genetic resources in apple has been initiated, since this crop gets more and more attention in the country. This project also supported evaluation of diversity within barley material grown by Kyrgyz farmers. Investigations in apple covered cultivars and in barley both cultivars and farmer's mixture populations.

Different types of analyses were performed depending on the aim of the study. Host plant resistance was evaluated with tests on seedlings (seedling resistance) and adult plants (adult plant resistance). Protein composition of Tajik wheat was evaluated by electrophoresis in polyacrylamide gels and protein concentration by High Performance Liquid Chromatography (HPLC). Genetic diversity in chickpea, apple and barley was evaluated with molecular markers, simple sequence repeats (SSR).

Scientific results

A number of wheat lines, carrying novel resistances to investigated pathogens and pests have been discovered. Furthermore, the plant material showed various degree of resistance, from high and moderate susceptibility to moderate and high resistance depending on alien chromatin involved and race/pathotype. Here we present some illustrative examples of novel (previously unknown) resistance to various pathogens and pests. Thus, tests for adult plant resistance to yellow rust identified novel resistance in rye chromosomes or chromosome fragments in several lines carrying the following substitutions and translocations: 1R (1D), 1RS.1DL, 2R (2D), 3R(3D), 3RS.3DL, 4R(4D), 5R(5D), 5RS.5AL. Furthermore, several lines were identified where resistance was introgressed from triticale and *Leymus racemosus*.

Concerning the resistance to stem rust var. Ug99, new sources of resistance have been identified in both adult plants, and seedling resistance tests in 1R+6R, 2R (2D), 4R (4D), as well as in genetic material of *Leymus racemosus* and *Thinopyrum junceiforme*. Genes and quantitative trait loci (QTL) conferring resistance in some of these lines are still to be identified. This work is in progress. Resistance to Russian wheat aphid (RWA) and Hessian fly were investigated in seedling tests. Novel resistance to RWA was found in 1R(1D), 1R(1D)+6R(6D), 5R(5D), and *Leymus Mollis*.

Concerning Hessian fly, previously unknown resistance was identified in 1R(1D), 1RS, 2R(2D). Several lines possessed a high level of resistance to all investigated pathogens and pests. However, the majority of lines show only partial resistance, often with a moderate effect. Further investigations are needed to identify the genes important for resistance, and transfer these into locally adapted wheat cultivars.

One of the important components influencing bread making quality is composition of high molecular weight glutenin subunits (HMW-GS), components of grain proteins which are produced during grain filling. The most common HMW-GS composition in Tajik wheat were 2* encoded on chromosome 1A, 7+9 encoded on chromosome 1B and 5+10 on chromosome 1D. All of these are known to be associated with good baking quality.

The genetic diversity in Kyrgyz chickpea has been assessed using molecular markers. The results indicate that Kyrgyz chickpea material is rather different from reference material from ICARDA and Spain. Furthermore, several lines have shown high protein content (around 30 %).

Apple has its origin in the forests of Kazakstan and Kyrgyzstan and thus genetic diversity is expected to be high. Molecular analyzes confirmed this assumption, though Kazakh apples were more different from Swedish varieties, compared to Kyrgyz. Genetic diversity of barley grown in the farmer's fields appeared to be unexpectedly high, which indicates that growers cultivate cultivar mixtures, probably to face challenges imposed by limited resources in Kyrgyz agriculture.

Dissemination of results

The scientific results have been communicated to research colleagues in a number of publications, and on scientific conferences and workshops. Swedish researchers together with a colleague from ICARDA have visited Tajikistan. Furthermore, a number of meetings and student seminars have been arranged in Alnarp.

Tight communication and collaboration between public and private sectors have been established. In Tajikistan, promising wheat lines were tested

"A number of wheat lines, carrying novel resistances to investigated pathogens and pests have been discovered"

Fotograf Ferit Turanli

Staffan Andersson and Asmaa Dabous planting seeds for trials with Russian wheat aphid in green house, at ICARDA, Aleppo, Syria.

in collaboration with a private farm (Latif Murodov) and in Sweden – in collaboration with Lantmännen SW thus building a base for future commercialisation of valuable plant materials.

The project had significant impact on capacity building. Post-doc Staffan Andersson and Lic student, Mahbubjon Rahmatov were exposed to research environments in CGIAR institutions, where they could establish several scientific collaborations. These collaborations resulted in a number of papers and presentations on conferences. Several research project applications have been submitted and granted. Furthermore, Mahbubjon Rahmatov has been granted a stipend from the Monsanto Beachel-Bourlag fund to continue to a PhD degree. This project supported PhD education on genetic diversity in barley during the last five months. Birjan Usubaliev graduated in May 2013.

Elnura Torutaeva and Marufqul Mahkamov started their MSc and Lic education. SLU-students lectured undergraduate students at the Kyrgyz Agrarian University and the Tajik Agrarian University.

Gender aspects

The project catered for gender aspects at all stages and levels. Thus, the project leader Larisa Gustavsson is female and the initiator of the project Tomas Bryngelsson is male. Eva Johansson and Larisa Gustavsson, the main supervisors of the students, are females, while both genders are represented among the co-supervisors, Hafiz Muminjanov, Staffan Andersson, Ramune Kuktaite and Rodomiro Ortiz. The most important aspect is that students of both gender were involved in education, M. Rahmatov and M. Mahkamov are males and Elnura Torutaeva is a female. These persons serve as the model for successful professionals of both genders for other students.

Greatest value of the program

The greatest value of the program is the contribution to education of young researchers from two Central Asian countries, Tajikistan and Kyrgyzstan, within plant breeding and genetic resources. The students gained knowledge of modern technologies and became part of the international scientific community. Furthermore, there is a great value of the discovered sources of resistance and other desirable traits for the long term breeding of resistant wheat cultivars, especially for the wide range of investigated pests and pathogens. This is believed to benefit many of the countries involved in the collaborations, thanks to the program. Thus, this project will have a long-term impact.

This project resulted in consecutive projects on genetics of resistance in wheat. There is a great potential to develop new projects on quality aspects in wheat and chick pea. Knowledge about degree and structure of genetic diversity in the investigated crops will help to improve preservation and utilisation of genetic resources of chick pea, apple and barley in Tajikistan and Kyrgyzstan. Established collaborations with universities in Central Asia and GGIAR institutes will continue, and, hopefully, result in extensive multilateral research and development projects.

A summary of the statistics for this project on p.176

Women are most often responsible for the dairy cows around Dushanbe.
Photo Elisabeth Lindah

11. Improved animal health systems for control of zoonoses

Improved animal health systems for control of zoonoses

Project leader: Ulf Magnusson

Summary in Swedish

Förbättrade system för kontroll av zoonoser

Tajikistan, grannland till Afganistan och Kina, var den fattigaste av republikerna i det forna Sovjetunionen, men hade stora kollektivjordbruk för bomull och boskap. Efter Sovjetunionens fall har andelen småjordbruk ökat (80% av hushållen håller nu boskap) samtidigt som den statliga veterinära hälsovården urholkats. En entreprenöriell verksamhet som nu pågår är småskalig mjölkproduktion runt större städer, där producenter säljer direkt till konsumenterna.

I detta samarbetsprojekt mellan forskare från Tajik Agrarian University (TAU) och SLU har vi visat att en betydande andel av mjölkkorna smittas av den i Sverige utrotade och fruktade sjukdomen Brucellos. Sjukdomen orsakar bland annat aborter och nedsatt mjölkproduktion hos nötkreatur och kan också spridas till människor. Spridningen till människor sker bl.a. via opastöriserad mjölk och orsakar återkommande feber och ledbesvär. Våra studier visar bland annat att en stor del av producenterna både säljer och dricker okokt (opastöriserad) mjölk, vilket utgör ett reellt hot mot folkhälsan. *Brucella*-infektionens negativa påverkan på såväl djurhälsa som folkhälsa äventyrar de ökande inkomster och utveckling bland de fattiga småbrukare som driver stadsnära mjölkproduktion i Tajikistan. TAU och SLU stödjer nu Tajikiska myndigheters arbete med att kontrollera denna smitta mellan djur och människa.

Summary

Tajikistan, which neighbours Afghanistan and China, was the poorest of the former Soviet republics, but had large collective farms for cotton and livestock. Following the Soviet collapse, the number of smallholdings (80% of which include livestock) has increased simultaneously with a deterioration of the governmental veterinary service. In this setting, small-scale dairy farming has been established in peri-urban areas of large towns, and producers sell directly to consumers as an entrepreneurial activity to improve livelihoods.

In this research cooperation between Tajik Agrarian University (TAU) and SLU we have shown that a considerable proportion of the dairy cows have been exposed to brucellosis – a disease that is globally feared but fortunately eradicated in Sweden. The disease causes abortions and reduced milk production in dairy cows and can be transmitted to humans via consumption of unpasteurised milk, where it causes undulant fever and arthritis. Our studies show that a large proportion of the producers sell and drink un-boiled (unpasteurised) milk, which is a real threat to public health. The negative impact by *Brucella* infection on livestock as well as public health, jeopardises the increasing incomes and development among poor small holders that are conducting peri-urban milk production in Tajikistan. TAU and SLU are currently supporting Tajik authorities in controlling this disease transmission between livestock and humans.

Background

Several of the former low-income Soviet Union republics had many of the large state or collective agricultural operations. These have since been replaced by smaller family owned units. Governmental public veterinary services have often deteriorated because of poor funding, which has led to weak animal health systems. This, in turn, has increased the risk for contagious diseases such as zoonoses, i.e. infectious diseases that are spread from animals to humans or vice versa, in small scale family farms with livestock. Previously SLU has, together with other Swedish veterinary expert agencies, been running a development project in Tajikistan aiming to improve the efficiency of the public veterinary system and in-

Making an interview at a houshold in the periphery of Dushanbe, Tajikistan.

Photo: Karin Jonasson

Photo: Elisabeth Lindahl

At livestock markets – this one just outside Dushanbe – there is a large risk that infectious diseases are spread among animals.

crease the knowledge of governmental veterinarians and university teachers about contagious livestock diseases.

In Tajikistan, as in many other countries in Central Asia and Middle East, the zoonosis brucellosis (caused by the bacteria *Brucella*) is identified as a severe animal and public health issue. Veterinary authorities and FAO have therefore conducted vaccination campaigns in rural areas. The current project however, had as the overall aim to reduce the risk of the spread of brucellosis within urban and peri-urban farming. This type of farming is a market driven farming practice that contributes to improved food security in cities and increased incomes for households with livestock. The aim was to investigate the presence of *Brucella* infection among ruminants in and around the capital Dushanbe, possible routes of transmission to the animals and from the animals to humans, and investigate the level of farmers' knowledge about, and attitudes to, the disease.

Collaborators

SLU

Ulf Magnusson (project leader), Elisabeth Lindahl (PhD student), Isabelle Ljung, Cecilia Grahn (both MSc students) – Dept. of Clinical Sciences

Sofia Boqvist, Shaman Muradrasoli – Dept. of Biomedical Sciences and Veterinary Public Health

Tajik Agrarian University

Nosirjon Sattorov (coordinator), with support from Izzatullo Sattori (rector).

Approach

In discussions between the partners and the Tajik Veterinary Services, the disease brucellosis in peri-urban farming was selected as the type-disease that should be studied in the project. The study included designing of the sampling in a systematic way to be able to draw scientifically sound conclusions. Sampling of blood from animals (n=905) and interviews of farmers regarding knowledge, attitudes and practices related to brucellosis was performed in 438 households around Dushanbe

during two periods of in total five weeks during 2011. The location of each household was recorded by Geographic Position System (GPS). Blood samples were processed at TAU and sent to SLU for serological analyses for *Brucella* using Elisa. Thereafter all data were processed statistically and by Geographic Information Systems (GIS). Swedish scientists have participated in the field work in Tajikistan and at a final seminar at TAU. Tajik scientists have participated in one course at SLU and in running Elisa-analyses at SLU. Reports have been produced together by SLU and TAU partners.

Scientific results

We found that 4.2% of the investigated herds had at least one cow showing serological evidence of infections and overall 2.1 % of the cows were positive. The proportion of infected herds is thus regarded as high. It was confirmed that serological evidence of *Brucella* infection in a herd was positively associated with abortions ($p<0.02$), stressing the animal health and economic aspects of the disease. Larger herds (more than 8 cattle) showed a higher risk than smaller herds to be infected ($p=0.02$), which is consistent with current knowledge about *Brucella* epidemiology among cattle in rural settings. However, somewhat unexpected, we found no association ($p>0.05$) between serological evidence of infection and the type of pasture – i.e. if the cattle in the household had communal grazing ground or if they were confined. We also found indications, which need further investigations, of a geographical clustering of the disease in one area.

The interviews showed that there was a positive association (<0.001) between the level of education among the farmers and the knowledge about brucellosis at large, but as many as 63% of the interviewed want more information about the disease. As many as 18% of the interviewees sold unpasteurised (un-boiled) milk, and 28% consumed it. This is alarming since the *Brucella* bacteria can be transmitted from infected cows to humans via unpasteurised milk.

Another risk situation for transmission of the infection to humans is at calving; women alone assisted at calving in 56% and, together with a male, in 13% of the households. This poses women at higher risk for attracting the disease. Over all, in 78% of the households, women had the main responsibility for the cows, suggesting that interventions for improved control of the disease in cows should be directed to the women in the family.

Dissemination of results

The project has so far generated two full papers, one that is submitted for publication and one that is in the final manuscript version:
There have been three abstracts prepared for scientific meetings.

In addition, two Swedish MSc theses that have taken advantage of the project cooperation between SLU and TAU have been produced.

Regarding capacity building, one course with nine colleagues from Tajikistan (TAU and Governmental Agencies) on Control of Infectious Diseases in Livestock was held at SLU in December 2011. Two TAU-colleagues visited SLU in September 2012 during two weeks for training in laboratory techniques. Then equipment and skills for ELISA-analyses were transferred from SLU to TAU.

In April 2013, a workshop was held at TAU presenting the outcome of the project for Tajik stakeholders like the Chief Veterinary Officer of Tajikistan, representatives from the Ministry of Agriculture and the Ministry of Public Health, the Medical University of Tajikistan and TAU. Also representatives from FAO attended the workshop in which the 24-page booklet "TAU-SLU research on zoonotic diseases in peri-urban animal farming in district of republican subordination" was distributed to the 30 participants.

Photo: Elisabeth Lindahl

Herding cows in the suburbs of Dushanbe, Tajikistan.

"As many as 18% of the interviewees sold unpasteurised (unboiled) milk, and 28% consumed it, which is alarming since the *Brucella* bacteria can be transmitted from infected cows to humans via unpasteurised milk"

Photo: Karin Jonasson

Collecting blood samples in a village for *Brucella* analysis.

Gender aspects

The majority of the SLU team are females, whereas the opposite holds true for the TAU-team. During courses and seminars in Sweden and Tajikistan persons of both genders from both parties have participated. The often challenging field work in Tajikistan has, from the SLU side, been performed by female staff. They gained a lot of respect and have been officially acknowledged for this, and may thus serve as role models.

The research as such has had a clear gender perspective, where the role of the different genders in animal farming as well as their differential risk for exposure to the *Brucella* bacteria have been investigated. These investigations showed that females were most often responsible for the cows in the household, which in turn suggests that interventions related to the keeping of cows should be communicated to the women in the household. Also, women most often assisted during calving and were also milking the cows, thus putting themselves more at risk to infection. The latter suggests that prevention campaigns for brucellosis should preferably be direct towards women.

Greatest value of the program

The main achievements of the program are that the capacity to generate scientifically solid data as a basis for modern, risk-based control of zoonotic diseases in livestock has been strengthened amongst the colleagues in Tajikistan. This is an important outcome of this close cooperation. Furthermore, Swedish colleagues have been exposed to the constraints and possibilities to generate this kind of data in a Central Asian country. It is of great value that the data generated in this university cooperation were so well received by the authorities responsible for controlling zoonotic diseases in Tajikistan. Taken together, this forms a platform for further work towards controlling infectious diseases in livestock for the sake of improved public and animal health and, ultimately, enhanced food security.

Finally, a strong partnership between researchers at TAU and SLU is now established and those involved are acting close together on the international research arena. This has generated common grant applications to the Swedish Linnaeus-Palme programme and the European Union.

A summary of the statistics for this project on p.177

Appendices

Program summary statistics

No. of projects: 24		Budget: 40 000 000 SEK
Collaborations		
No. of countries: 23	No. of academic institutions: 29	No. of other organisations: 34

Publications	
Published in peer reviewed scientific journals	17
Manuscripts for peer reviewed scientific journals	61
Book chapters/conference proceedings	30
Popular science publications	10
Master/Bachelor theses	60
Defended at collaborating academic institutions	33
Defended at SLU	27
Pamphlets/teaching materials	25

Activities organised	
Scientific conferences/workshops	21
Courses/training activities	28
Workshops/courses for end users	27

Countries	Page
Brazil	32
Burkina Faso	84, 90
Canada	32
Denmark	100, 124
Ethiopia	42, 46, 60, 70, 84, 108, 114
Ghana	100
Kenya	18, 38, 42, 46, 60, 64, 74, 78, 84, 114, 124
Kyrgyzstan	124
Malawi	100
Mexico	124
Mocambique	100
South Africa	108, 114, 118
Sweden	38, 90, 100, 118
Switzerland	32
Syria	124
Tajikistan	124, 130
Tanzania	90
The Netherlands	100
Uganda	14, 24, 28, 32, 38, 42, 52, 56, 64, 100
USA	100, 124
Vietnam	96
Zambia	100, 108
Zimbabwe	108

Academic institutions	Page
Addis Ababa University, Ethiopia	46, 70
Federal University of Santa Catarina, Brazil	32
Gotenburg University, Sweden	90
Haramaya University, Ethiopia	42
Hawassa University, Ethiopia	70, 84
Jomo Kenyatta University of Agriculture and Technology, Kenya	78, 84
Kyrgyz Agrarian University, Kyrgyzstan	124
Lund University, Sweden	38, 100, 118
Makerere University, Kampala, Uganda	14, 24, 28, 32, 38, 42, 52, 56, 64
Michigan State University, USA	100
Moi University, Kenya	18, 74
Nairobi University, Kenya	74
Rongo University College, Rongo, Kenya	18
Sokoine University of Agriculture, Tanzania	90
Stellenbosch University, South Africa	108, 118
Tajik Agrarian University, Tajikistan	124, 130
University of Addis Ababa, Ethiopia	46, 70
University of British Columbia, Canada	32
University of Copenhagen, Denmark	100
University of Eldoret, Eldoret, Kenya	18
University of Ghana, Ghana	100
University of Kwazulu Natal, South Africa	114
University of Minnesota, USA	124
University of Ouagadougou, Burkina Faso	90
University of Pretoria, South Africa	114, 118
University of the Free State, South Africa	108, 118
University of Zambia, Zambia	100
Uppsala University, Sweden	78, 100
Wollo University, Ethiopia	108

Other collaborating organisations	Page
Animal Industry and Fisheries, Entebbe, Uganda	64
Arbaminch Plant Health Clinic, Ethiopia	46, 114
CIAT (International Center for Tropical Agriculture), Kenya	74, 84
CIMMYT, International Maize and Wheat Improvement Center, Mexico	124
CIP (International Potato Center), Kenya	42
CMRTE (Chinangwandi Mbatata Roots and Tubers Association), Malawi	100
Eawag: Swiss Federal Institute of Aquatic Science and Technology	32
EIAR (The Ethiopian Institute for Agricultural Research)	60
EIWR (Ethiopian Institute for Water Resources), Addis Ababa University, Ethiopia	70
Holetta Agricultural Research Center, Ethiopia	46
IIAM (Instituto de Investigação Agrária de Mocambique), Mocambique	100
ICARDA (International Center for Agricultural Research in Dry Areas), Syria	124
icipe (International Center for Insect Physiology and Ecology), Kenya	38, 46, 114
ICRAF (World Agroforestry Centre), Kenya	78, 84
IITA (International Institute of Tropical Agriculture), Kenya	74, 100
ILRI (International Livestock Research Institute), Ethiopia/Kenya	60, 64, 84
INERA (Institut de l'Environnement et des Recherches Agricoles), Burkina Faso	84
KARI (Kenya Agricultural Research Institute), Kenya	124
Ministry of Agriculture, Ethiopia	60
Ministry of Agriculture, Animal Industry and Fisheries, Uganda	64
Ministry of Livestock Development, Kenya	60
MUARIK (Makerere University Agricultural Research Institute), Uganda	32
NARO (National Agricultural Research Organisation), Uganda	100
NaSARRI (National Semi Arid Resources Research Institute), Uganda	14
Plant Resources Center, Vietnam Academy of Agricultural Sciences, Vietnam	96
Programme against Malnutrition, Zambia	100
Rural Women Foundation, The Netherlands	100
SARRNET (Southern Africa Root Crops Research Network), Malawi	100
SASRI (South African Sugercane Research Institute), South Africa	114, 118
Seed Services, Department of Research and Specialist Services, Zimbabwe	108
UAAIE (Upper Awash Agro Industry Enterprise), Ethiopia	46
Uganda Wildlife Authority, Uganda	64
Vi Agroforestry Programme, Kenya	78
Zambia Agriculture Research Institute, Zambia	108

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39. Nyberg, Y., I. Öborn, M. Jonsson, E. Laszlo Ambjörnsson and F.L. Sinclair. "Identification of adaptation and coping measures to rainfall variability in two contrasting areas." 78
40. Okoth, C., S. Rutherford, A. Juergensen, T. Dekker and D. Conlong. "Parasitoid recognition of host-induced cues in sugarcane and sedge." 114
41. Onkware, Augustino Osoro, Emily Jepkosgei Too, Beatrice Ang'iyo Were, Joyce Agalo, Dorothy Akinyi Onyango, Rosabella Jemurgor, Samuel Gudu and Anders S Carlsson. "Distribution of, and genetic diversity and resources of Yellow Nutsedge in Eest Africa." 18
42. Perez Teran, A.S., M.K. Dumas-Johansen, D. Catacutan, Q.H. Nguyen, M.H. Hoang, I. Enjebo, L. Öborn, J.M. Gathenya, P.N. Mwangi and I. Öborn. "Climate, water and livelihoods: adaptation strategies in the humid highlands of Kenya." 78
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44. Rahmatov, M., S.C. Andersson, L. Garkava-Gustavsson and E. Johansson. "Stem rust adult plant and seedling resistances in 1BL.1RS and 2RL.2BS double wheat-rye translocation lines." 124
45. Rock, K., S. Muradrasoli, D. Rwabiita Mugusi, U. Magnusson and S. Boqvist. "Prevalence and detection of *Brucella abortus* in cattle milk collected in peri-urban regions in Gulu and Soroti Regions of Uganda." 24
46. Rock, K., D. Rwabiita Mugusi, K. Ståhl, U. Magnusson and S. Boqvist. "Risk points in the informal milk chains in two contrasting regions in northern and eastern Uganda." 24
47. Rusinamhodzi, L., A.S. Dahlin, M. Corbeels. "Intensification options for the extensive farming systems of central Mozambique: application of the NUANCES framework." 78
48. Rwabiita Mugusi, D., S. Boqvist, GW. Nasinyama, C. Waiswa, K. Ikwap, K. Rock, E. Lindahl, U. Magnusson and J. Erume. "Prevalence of, and factors associated with *Brucella abortus* sero-positivity in cattle in transitional urban and peri-urban farming systems in eastern and northern Uganda." 24
49. Röing de Nowina, K., O. Andrén, B. Vanlauwe, H. Kirchmann and T. Kätterer. "Application of biochar to humic ferrasols and humic nitisols in western and central Kenya - effect on crop yields and nutirent uptake during 10 growing seasons." 74
50. Stein, J., W. Mulatu, W. Ayalew, H. Lemecha, B. Malmfors, T. Dessie, J.E.O. Rege and J. Philipsson. "Production, reproduction and trypanotolerance in four ethiopian cattle breeds kept on station in a Tsetse infested area." 60
51. Tibezinda, M., D. Mpairwe, E. Sabiiti and E. Wredle. "Assessment of the on-farm feed resources availability and utilisation in the agro-pastoral system of south western Uganda." 52
52. Torutaeva, E. , A. Zborowska, R. Ortiz, K. Turgunbaev and L. Garkava-Gustavsson. "Are kyrgyz apples unique?" 124

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Book chapters

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Student theses (MSc and BSc)

Page

1. Aliro, Tony (MSc thesis, 2013). "The dynamics of African Swine Fever in a post-conflict area: the case of Gulu district in Northern Uganda". Makerere University, Uganda. 64
2. Alvum-Toll, Kajsa (MSc thesis, 2013). "*Allanblackia* - a tree under current domestication: what are the soil requirements?". Dept of Soil and Environment, Swedish University of Agricultural Sciences. 78
3. Axelsson, Johan (MSc thesis, 2013). "Tomato: enemy free space for the potato tuber moth in Ethiopia". Dept of Plant Protection Biology, Swedish University of Agricultural Sciences. 46
4. Backlund, Nina (MSc thesis, 2012). "The effects of shading and surrounding landscape composition on arthropod pest abundance in Coffea arabica plantation". Dept of Biology, Lund University. 38
5. Berntsson, Sabina, and Winberg, Josefine (BSc thesis, 2013). "The influence of water availability on land cover and tree functionality in smallholder farmer settlements. A minor field study in Trans Nzoia County, Kenya". Dept of Physical Geography and Ecosystem Science, Lund University, Sweden. 78
6. Blokland, Marjolene (MSc thesis, 2013 (pending)). "Effects of trees and livestock on aggregate stability on smallholder farms in Western Kenya". Vrije University, The Netherlands. 78
7. Brink, Matilda (BSc thesis, 2011). "Porcine viruses in Uganda: a study of TTSuV and PPV4 in wild and domestic pigs". Dept of Biomedical Sciences and Veterinary Public Health, Swedish University of Agricultural Sciences. 64
8. Budu, Agnes Simpson (MSc thesis, 2012). "Chemical composition and cyanogenic potential of traditional and high yielding CMD resistant cassava (*Manihot esculenta* Crantz) varieties". University of Ghana, Ghana. 100
9. Casselbrant, Madelene, and Lindqvist Ståhle, Siri. (BSc thesis, 2012). "Demand and perception of fertilizer: among small-holder farmers in Kenya". Dept of Economics, Swedish University of Agricultural Sciences. 74
10. Charles, Liri (MSc thesis, 2013). "Development of sorghum germplasm resistant to Striga, drought and turcicum leaf blight". Dept of Agricultural Production, Makerere University, Uganda. 14
11. Cornelissen, Paul (MSc thesis, 2013 (pending)). "Farmers perspective in comparison with scientific soil research in Trans Nzoia district Western Kenya". Vrije University, The Netherlands. 78
12. Dejene, Tibebe (MSc thesis, 2012). "Study on the electrophysiological and behavioural responses of the African Invasive Fruit Fly, *Bactrocera invadens* (d*iptera: tephritidae*) to semiochemicals". Dept of Zoology, Addis Ababa University, Ethiopia. 46
13. Eklundh, Camilla (MSc thesis, 2013). "The use of artificial insemination in dairy farms in urban/peri-urban Kampala, Uganda". Dept of Clinical Sciences, Swedish University of Agricultural Sciences. 56
14. Enjebo, Ida, and Öborn, Lisa (Minor Field Study no.165, 2012). "A farming system analysis on the slope of Mount Kenya. A study of how water resources and land use are affected by climate variability in two areas in Embu District, Kenya". Committee for Tropical Ecology, Uppsala University. 78
15. Eriksson, Sara (MSc thesis, 2013 (pending)). "Kontinuerlig process för proteinproduktion från gödsel (gris och human) samt organiskt avfall". School of Biotechnology, KTH Royal Institute of Technology. 32

Student theses (MSc and BSc), *continued*

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16. Fogelberg, Johan (MSc thesis, 2013 (pending)). "The roles of trees for water infiltration on farms in Trans Nzoia disstrict in western Kenya". Dept of Crop Production Ecology, Swedish University of Agricultural Sciences. 78
17. Frendberg, Linn (MSc thesis, 2012). "Evaluation of physical properties of left-over food collected from hotels and restaurants as pig feed in urban and peri-urban areas of Kampala". Dept of Animal Nutrition and Management, Swedish University of Agricultural Sciences. 28
18. Gayi, Dennis (MSc thesis, 2013). "Role of landscape grass diversity on maize stemborers and their natural enemy interactions". Dept of Crop science, Makerere University, Uganda. 38
19. Geiger, Armin (MSc thesis, 2013 (pending)). "Transcriptomic and proteomic analysis of plants and microbes". Stellenbosch University, South Africa. 108
20. Gichamo, Tesfanesh (MSc thesis, 2011). "Dispute or residing together in harmony? Bean cultivation and theft in rural Ethiopia". Dept of Urban and Rural Development, Swedish University of Agricultural Sciences. 70
21. Grahn, Cecilia (MSc thesis, 2013). "Brucellosis in small ruminants: an investigation of knowledge, attitude and practices in peri-urban farming around the region of Dushanbe, Tajikistan". Dept of Clinical Sciences, Swedish University of Agricultural Sciences. 130
22. Hansson, Ulrika (MSc thesis, 2012). "Ensiling characteristics of banana peelings". Dept of Animal Nutrition and Management, Swedish University of Agricultural Sciences. 28
23. Ijala, Anthony Raphael (MSc thesis, 2013). "Effect of shading and distance from Elgon's alpine vegetation on natural enemy-insect pest relationships on Arabica coffee in Uganda". Dept of Crop Science, Makerere University, Uganda. 38
24. Jemurgor, Rosabella (MSc thesis, 2013). "Taxonomy and cytology of wild and cultivated yellow nutsedge (*Cyperus esculentus*)". Dept of Biological Sciences, University of Eldoret, Kenya. 18
25. Jönsson, Ellen (MSc thesis, 2013). "Seroprevalence and risk factors for bovine brucellosis, salmonellosis and bovine viral diarrhea in urban and peri-urban areas of Kampala, Uganda". Dept of Biomedical Sciences and Veterinary Public Health, Swedish University of Agricultural Sciences. 24, 32
26. Jönsson, Emma (MSc thesis, 2013 (pending)). "Evaluation in quality parameters in South African sorghum". Dept of Plant Breeding, Swedish University of Agricultural Sciences. 108
27. Jönsson, Tina, and Rådman, Mika (BSc thesis, 2012). "Economic impact of fertilizers and improved seeds among smallholder farming systems in central and western Kenya". Dept of Economics, Swedish University of Agricultural Sciences. 74
28. Kasule, Lawrence (BSc thesis, 2012). "Nutritional properties of own-mixed chicken rations in urban/peri-urban areas of Kampala". School of Agricultural Sciences, Makerere University, Uganda. 28
29. Kimutai, Geoffrey (MSc thesis, 2013). "Low soil fertility and *Striga hermonthica* management using nitrogen fertilizers and host plant resistance in Bondo, Siaya, Vihiga counties". Dept of Soil Sciences, Moi University, Kenya. 74
30. Kindbom, Stephanie (MSc thesis, 2012). "Ensiling wet brewer's waste in peri-urban areas of Kampala, Uganda". Dept of Animal Nutrition and Management, Swedish University of Agricultural Sciences. 28
31. Larsson, Miriam (MSc thesis, 2013). "Soil fertility status and *Striga hermonthica* infestation relationship due to management practices in western Kenya". Dept of Soil and Environment, Swedish University of Agricultural Sciences. 74

Student theses (MSc and BSc), *continued*	Page
32. Lernfelt, Linn (MSc thesis, 2013). "Prevalence of antibodies for Peste des petits des ruminants virus and Brucella and related risk factors in goat herds in urban and peri-urban agriculture in Kampala". Dept of Biomedical Sciences and Veterinary Public Health, Swedish University of Agricultural Sciences.	24, 32
33. Liljestrand, Josefina (MSc thesis, 2012). "Breeding practices of Red Maasai sheep in Maasai pastoralist communities". Dept of Animal Breeding and Genetics, Swedish University of Agricultural Sciences.	60
34. Ljung, Isabel (MSc thesis, 2013). "Brucellosis in small ruminants: a seroprevalence study in peri-urban farming around the region of Dushanbe, Tajikistan". Dept of Clinical Sciences, Swedish University of Agricultural Sciences.	130
35. Madalcho, Aklilu Bajigo (MSc thesis, 2012). "The effect of land use change on soil physic-chemical properties over time in Munsea Shashemene, Oromia Region, Ethiopia". Wondo Genet College of Forestry and Natural Resources, Hawassa, Ethiopia.	70
36. Malmberg, Louise (BSc thesis, 2012). "The effects of shading and surrounding landscape composition on arthropod pest abundance in *Coffea arabica* plantations - A case study in the Tranz-Nzoia district of the rift valley province in western Kenya". Dept of Ecology, Swedish University of Agricultural Sciences.	38
37. Mechi, Atome Abebe (MSc thesis, 2013). "Rural women's livelihood vulnerability to climate change and their adaptation mechanisms: The case of Ada'a woreda, Oromia Region, Ethiopia". Dept of Geography and Environmental Studies, Addis Ababa University, Ethiopia.	70
38. Mekonnen, Bethilehem (MSc thesis, 2013). "Electrophysiological responses of *Bactrocera invadens* , *Bactrocera olea* and *Ceratitis capitata* to head space volatiles of mango and orange fruits". Dept of Zoology, Addis Ababa University, Ethiopia.	46
39. Mersha, Mulalem (MSc thesis, 2013). "Dispersal patterns of *Bactrocera invadens* in the terrains of the Southern Rift Valley area of Arbaminch, Ethiopia". Dept of Zoology, Addis Ababa University, Ethiopia.	46
40. Mkhatywa, Nomcebo (MSc thesis, 2013). "Baking quality and nutritional value in South African wheat". Dept of Crop Science, University of the Free State, South Africa.	108
41. Mulugeta, Tewodros (MSc thesis, 2013). "Behavioural response of *Diadegma mollipla* , a parasitoid, to potato tuber moth infested and non-infested different solanaceous species". Dept of Zoology, Addis Ababa University, Ethiopia.	46
42. Mwasa, Mwansa Nkonkola (MSc thesis, 2013). "Chemical composition and cyanogenic glycoside potentials of different cassava (*Manihot esculenta* Crantz) varieties from southeastern African regions". University of Zambia, Zambia.	100
43. Nabisubi, Regina (MSc thesis, 2013 (pending)). "Effect of drought on the productivity and persistence of forage plants in Agro-Pastoral systems of Uganda". Dept of Agricultural Production, Makerere University, Uganda.	52
44. Nambafu, Godfrey (MSc thesis, 2013). "Efficacy of farmers' soil fertility management practices in the control of *Striga hermonthica* : a case study of the samllholder farmers of Western Kenya". Department of Land Resource Management and Agricultural Technology Nairobi University, Kenya.	74
45. Ndyanabo, Suzan (MSc thesis, 2012). "A longitudinal sudy of ASF in domestic pigs in Masaka and Rakai". Makerere University, Uganda.	64
46. Njoroge, Anne (MSc thesis, 2013 (pending)). "Variability of *Phytophtora infestans* in Uganda and Kenya and its implications to late blight management in potato and tomato". Dept of Agricultural Production, Makerere University, Uganda.	42

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47. Nyberg, Emilia (BSc thesis, 2011). "Prevalence and genetic characterization of African Swine Fever virus in vectors and domestic pigs in Uganda". Dept of Biomedical Sciences and Veterinary Public Health, Swedish University of Agricultural Sciences. 64
48. Obasanjo, Patrick (MSc thesis, 2013). "Assessing soybean (Glycine-maxima (L) Merill) for managing *Striga hermonthica* and improving soil fertility in western Kenya". Dept of Soil Sciences, Moi University, Kenya. 74
49. Okalany, Emmanuel (BSc thesis, 2012). "Agronomic performance of advanced (pre-released) sorghum lines". Dept of Agricultural Production, Makerere University, Uganda. 14
50. Olsson, Jenny (MSc thesis, 2013). "Characterization of novel small porcine DNA viruses". Dept of Biomedical Sciences and Veterinary Public Health, Swedish University of Agricultural Sciences. 64
51. Onyango, Dorothy (MSc thesis, 2013). "Isolation and characterisation of acid tolerant groundnut (*Arachis hypogea* L.) rhizobia strains from western Kenya". Dept of Biological Sciences, University of Eldoret, Kenya. 18
52. Poultouchidou, Anatoli (MSc thesis, 2012). "Effects of forest plantations on soil carbon sequestration and farmers' livelihoods - A case study in Ethiopia". Dept of Soil and Environment, Swedish University of Agricultural Sciences. 70
53. Shikuri, Bernard (BSc thesis, 2013). "Characterisation of yellow nutsedge (*Cyperus esculentus* L) accessions using morphological traits". Dept of Biological Sciences, University of Eldoret, Kenya. 18
54. Ström, Helena (MSc thesis, 2013). "*Allanblackia* – a tree crop under current domestication: What are the important symbionts?". Dept of Forest Mycology and Plant Pathology, Swedish University of Agricultural Sciences. 78
55. Temu, Beatus (MSc thesis, 2012). "Carbon business scenarios and communities' choices under REDD+ in Lindi Rural district, Tanzania". Sokoine University of Agriculture, Tanzania. 90
56. Thieffry, Axel (MSc thesis, 2013). "Yellow Nutsedge (*Cyperus esculentus* L.) : early and late developmental RNA-seq analyses of tuberous tissues accumulating lipids". Dept of Animal Genetics, Swedish University of Agricultural Sciences. 18
57. Weighill, Debbie (BSc thesis, 2013). "Parallelization of OrthoMCL and phylogenomic analysis of gene families". Stellenbosch University, South Africa. 108
58. Vuong, Thao Thi Phuong (MSc thesis, 2012). "Farmers' perceptions of the "Unleashing the Power of Cassava in Africa in Response to the Food Crisis" (UPoCA) project: Experiences from Malawi". Department of Earth Sciences, Uppsala University. 100
59. Yeboah, Yaw (MSc thesis, 2013). "Gendering the REDD+ policy process in Ghana". Dept of Urban and Rural Development, Swedish University of Agricultural Sciences. 90

PhD/Licentiate students supported by the program

Disease breeding in sorghum – MAS technology and dissemination of information, *p. 14*

Project leader: Christina Dixelius | Budget: 1 500 000 SEK

Collaborations

Countries:	Academic institutions:	Other organisations:
- Uganda	- Makerere University, Kampala, Uganda	- NaSARRI - the National Semi Arid Resources Research Institute, Entebbe, Uganda

Publications

Published in peer reviewed scientific journals	0
Manuscripts for peer reviewed scientific journals	0
Book chapters/conference proceedings	1

Martin, T., Biruma, M., Fogelqvist, J., Okori, P., and Christina, D. (2013). **Unlocking the potential of Sorghum for development in East Africa**. In Sorghum: Production, Growth Habits and Health Benefits (Nova Publ.).

Popular science publications	0
Master/Bachelor theses	2

Charles, Liri (MSc thesis, 2013). **Development of Sorghum germplasm resistant to Striga, drought and turcicum leaf blight**. Dept of Agricultural Production, Makerere University, Uganda.

Okalany, Emmanuel (BSc thesis, 2012). **Agronomic performance of advanced (pre-released) sorghum lines**. Dept of Agricultural Production, Makerere University, Uganda.

Pamphlets/teaching materials	1

The production of an E-book with free access was planned at the sorghum workshop, held in Entebbe, Uganda 2011.

Activities organised

Scientific conferences/workshops	1

Sorghum workshop 13-18 October 2011, Entebbe, Uganda, Organizers P. Okori & C. Dixelius

Courses/training activities	2

PhD course “Plant breeding & crop production – meeting the 2050 food security demands” 4.5 HEC, 16-20 May, 2011.

PhD course “Agrigenomics” 4 HEC, Organism Biology research school, SLU 14 Dec. 2012 - 27 Feb. 2013.

Workshops/courses for end users	3

Genetic resources of yellow nutsedge *(Cyperus esculentus* L.*)* in Kenya and parts of East Africa, *p. 18*

Project leader: Anders Carlsson | Budget: 1 500 000 SEK

Collaborations

Countries:	Academic institutions:	Other organisations:
- Kenya	- Moi University, Eldoret, Kenya - Rongo University College, Rongo, Kenya - University of Eldoret, Eldoret, Kenya	

Publications

Published in peer reviewed scientific journals	0
Manuscripts for peer reviewed scientific journals	3

Onkware, A.O., Too, E.J., Were, B.A., Agalo, J., Onyango, D.A., Jemurgor, R., Gudu, S., and Carlsson, A.S. **Distribution of, and genetic diversity and resources of yellow nutsedge in East Africa**.

Were, B.A., Onkware, A.O., Too, E.J., Ouma, E., Gudu, S., and Carlsson, A.S. **The potential of using yellow nutsedge as a new crop in Kenya taking in consideration agronomic and quality performance**.

Were, B.A., Too, E.J., Onkware, A.O., Gudu, S., Carlsson, A.S., and Geleta, M. **Development of microsatellite markers (SSR markers) for yellow nutsedge (*C. esculentus* L.)**.

Book chapters/conference proceedings	0
Popular science publications	0
Master/Bachelor theses	4

Jemurgor, Rosabella (MSc thesis, 2013). **Taxonomy and cytology of wild and cultivated yellow nutsedge (*Cyperus esculentus*)**. Dept of Biological Sciences, University of Eldoret, Kenya.

Onyango, Dorothy (MSc thesis, 2013). **Isolation and characterisation of acid tolerant groundnut (*Arachis hypogea* L.) rhizobia strains from western Kenya**. Dept of Biological Sciences, University of Eldoret, Kenya.

Shikuri, Bernard (BSc thesis, 2013). **Characterisation of yellow nutsedge (*Cyperus esculentus*,L) accessions using morphological traits**. Dept of Biological Sciences, University of Eldoret, Kenya.

Thieffry, Axel (MSc thesis, 2013). **Yellow Nutsedge (*Cyperus esculentus* L.) : early and late developmental RNA-seq analyses of tuberous tissues accumulating lipids**. Dept of Animal Genetics, Swedish University of Agricultural Sciences.

Pamphlets/teaching materials	1

Activities organised

Scientific conferences/workshops	1
Courses/training activities	1
Workshops/courses for end users	2

Brucella infections among cattle in urban and peri-urban areas in Uganda, *p. 24*

Project leader: Sofia Boqvist | Budget: 3 000 000 SEK

Collaborations

Countries:	Academic institutions:	Other organisations:
- Uganda	- Makerere University, Kampala, Uganda	- MUARIK (Makerere University Agricultural Research Institute), Uganda

Publications

Published in peer reviewed scientific journals	0
Manuscripts for peer reviewed scientific journals	4

Blomström, A.-L., Lalander, C., Komakech, A.J., Vinneras, B., and Boqvist, S. **Circulation of viral and bacterial zoonotic agents early in the primary production chain in Uganda**.

Rock, K., Muradrasoli, S., Rwabiita Mugusi, D., Magnusson, U., and Boqvist, S. **Prevalence and detection of Brucella abortus in cattle milk collected in peri-urban regions in Gulu and Soroti regions of Uganda**.

Rock, K., Rwabiita Mugusi, D., Ståhl, K., Magnusson, U., and Boqvist, S. **Risk points in the informal milk chains in two contrasting regions in Northern and Eastern Uganda**.

Rwabiita Mugusi, D., Boqvist, S., Nasinyama, G., Waiswa, C., Ikwap, K., Rock, K., Lindahl, E., Magnusson, U., and Erume, J. **Prevalence of, and factors associated with Brucella abortus sero-positivity in cattle in transitional urban and peri-urban farming systems in eastern and northern Uganda**.

Book chapters/conference proceedings	0
Popular science publications	0
Master/Bachelor theses	2

Jönsson, Ellen (MSc thesis, 2013). **Seroprevalence and risk factors for bovine brucellosis, salmonellosis and bovine viral diarrhea in urban and peri-urban areas of Kampala, Uganda**. Dept of Biomedical Sciences and Veterinary Public Health, Swedish University of Agricultural Sciences.

Lernfelt, Linn (MSc thesis, 2013). **Prevalence of antibodies for Peste des petits des ruminants virus and Brucella and related risk factors in goat herds in urban and peri-urban agriculture in Kampala**. Dept of Biomedical Sciences and Veterinary Public Health, Swedish University of Agricultural Sciences.

Pamphlets/teaching materials	0

Activities organised

Scientific conferences/workshops	0
Courses/training activities	1
Workshops/courses for end users	1

Feed for livestock in urban and peri-urban areas in Uganda, *p. 28*

Project leader: Jan Erik Lindberg | Budget: 1 000 000 SEK

Collaborations

Countries:	Academic institutions:	Other organisations:
- Uganda	- Makerere University, Kampala, Uganda	

Publications

Published in peer reviewed scientific journals: 2

Katongole, C.B., Nambi-Kasozi, J., Lumu, R., Bareeba, F., Presto, M., Ivarsson, E., and Lindberg, J.E. (2012). **Strategies for coping with feed scarcity among urban and peri-urban livestock farmers in Kampala, Uganda**. J Agr Rural Dev Trop *113*, 165-174.

Lumu, R., Katongole, C., Nambi-Kasozi, J., Bareeba, F., Presto, M., Ivarsson, E., and Lindberg, J. (2013). **Indigenous knowledge on the nutritional quality of urban and peri-urban livestock feed resources in Kampala, Uganda**. Trop Anim Health Prod, 1-8.

Manuscripts for peer reviewed scientific journals: 2

Kasule, L., Katongole, C.B., Nambi-Kasozi, J., Lumu, R., Bareeba, F., Presto, M., Ivarsson, E., and Lindberg, J.E. **Nutritional properties of own-mixed chicken rations in urban and peri-urban areas of Kampala**.

Lumu, R., Katongole, C.B., Nambi-Kasozi, J., Bareeba, F., Presto, M., Ivarsson, E., and Lindberg, J.E. **Nutritional quality of urban and peri-urban livestock feed resources in Kampala, Uganda**.

Book chapters/conference proceedings: 0

Popular science publications: 0

Master/Bachelor theses: 4

Frendberg, Linn (MSc thesis, 2012). **Evaluation of physical properties of left-over food collected from hotels and restaurants as pig feed in urban and peri-urban areas of Kampala**. Dept of Animal Nutrition and Management, Swedish University of Agricultural Sciences.

Hansson, Ulrika (MSc thesis, 2012). **Ensiling characteristics of Banana peelings**. Dept of Animal Nutrition and Management, Swedish University of Agricultural Sciences.

Kasule, Lawrence (BSc thesis, 2012). **Nutritional properties of own-mixed chicken rations in urban/peri-urban areas of Kampala**. School of Agricultural Sciences, Makerere University, Uganda.

Kindbom, Stephanie (MSc thesis, 2012). **Ensiling wet brewer's waste in peri-urban areas of Kampala, Uganda**. Dept of Animal Nutrition and Management, Swedish University of Agricultural Sciences.

Pamphlets/teaching materials: 5

Activities organised

Scientific conferences/workshops: 0

Courses/training activities: 1

Workshops/courses for end users: 2

Manure management, *p. 32*

Project leader: Björn Vinnerås | Budget: 1 000 000 SEK

Collaborations

Countries:	Academic institutions:	Other organisations:
- Brazil - Canada - Switzerland - Uganda	- Makerere University, Kampala, Uganda - University of British Columbia, Canada - Federal University of Santa Catarina, Brazil	- MUARIK (Makerere University Agricultural Research Institute), Uganda - EAWAG (Swiss Federal Institute of Aquatic Sciences and Technology), Switzerland

Publications

Published in peer reviewed scientific journals: 2

Komakech, A., Banadda, N., Gebresenbet, G., and Vinnerås, B. (2013). **Maps of animal urban agriculture in Kampala City**. Agron Sustain Dev, 1-8.

Lalander, C., Diener, S., Magri, M.E., Zurbrugg, C., Lindstrom, A., and Vinnerås, B. (2013). **Faecal sludge management with the larvae of the black soldier fly (*Hermetia illucens*)--from a hygiene aspect**. The Science of the total environment *458-460*, 312-318.

Manuscripts for peer reviewed scientific journals: 3

Komakech, A.J., Kinobe, J.R., Banadda, N.E., Sundberg, C., Gebresenbet, G., and Vinnerås, B. **Characterisation of municipal waste in Kampala, Uganda**.

Lalander, C., Hill, G.B., and Vinnerås, B. **Hygiene quality in urine diverting vermicomposting toilets**.

Lalander, C., Komakech, A.J., and Vinnerås, B. **Vermicomposting of manure and food waste - a case study from Kampala**.

Book chapters/conference proceedings: 1

Proceedings of the Second International Faecal Sludge Management conference (FSM2), Durban, South Africa, 2012.

Popular science publications: 2

Omvärlden, http://www.sida.se/OmVarlden/Varlden/Briefing/Fluglarver-forvandlar-dynga-till-djurfoder/

Uppsalanyheter.se, http://uppsalanyheter.se/nyheter/oevrigt/item/1563-godsel-blir-djurfoder

Master/Bachelor theses: 2

Jönsson, Ellen (MSc thesis, 2013). **Seroprevalence and risk factors for bovine brucellosis, salmonellosis and bovine viral diarrhea in urban and peri-urban areas of Kampala, Uganda**. Dept of Biomedical Sciences and Veterinary Public Health, Swedish University of Agricultural Sciences.

Lernfelt, Linn (MSc thesis, 2013). **Prevalence of antibodies for Peste des petits des ruminants virus and Brucella and related risk factors in goat herds in urban and peri-urban agriculture in Kampala**. Dept of Biomedical Sciences and Veterinary Public Health, Swedish University of Agricultural Sciences.

Pamphlets/teaching materials: 1

Activities organised

Scientific conferences/workshops	0
Courses/training activities	0
Workshops/courses for end users	0

The importance of landscape and local factors for biological control, *p. 38*

Project leader: Barbara Ekbom

Budget: 1 000 000 SEK

Collaborations

Countries:	Academic institutions:	Other organisations:
- Kenya - Sweden - Uganda	- Makerere University, Kampala, Uganda - Lund University	- *icipe* (International Center for Insect Physiology and Ecology), Kenya

Publications

Published in peer reviewed scientific journals	0
Manuscripts for peer reviewed scientific journals	0
Book chapters/conference proceedings	1

Gamés-Virués, S., Jonsson, M., and Ekbom, B. (2012). **The ecology and utility of local and landscape scale effects in pest management**. In Biodiversity and insect pests: key issues for sustainable management, Gurr GM, Wratten SD, Snyder WE, Read DMY, ed. (Chichester, U.K.: John Wiley and Sons Ltd.), pp. 106-120.

Popular science publications	0
Master/Bachelor theses	4

Backlund, Nina (MSc thesis, 2012). **The effects of shading and surrounding landscape composition on arthropod pest abundance in *Coffea arabica* plantation**. Dept of Biology, Lund University.

Gayi, Dennis (MSc thesis, 2013). **Role of landscape grass diversity on maize stemborers and their natural enemy interactions**. Dept of Crop science, Makerere University, Uganda.

Ijala, Anthony Raphael (MSc thesis, 2013). **Effect of Shading and didstance from Elgon's alpine vegetation on natural enemy-insect pest relationships on Arabica coffee in Uganda**. Dept of Crop Science, Makerere University, Uganda.

Malmberg, Louise (BSc thesis, 2012). **The effects of shading and surrounding landscape composition on arthropod pest abundance in *Coffea arabica* plantations - A case study in the Tranz-Nzoia district of the rift valley province in western Kenya**. Dept of Ecology, Swedish University of Agricultural Sciences.

Pamphlets/teaching materials	0

Activities organised

Scientific conferences/workshops	2
Courses/training activities	2
Workshops/courses for end users	0

Epidemiological studies to determine the impact of resistance in controlling plant diseases, *p. 42*

Project leader: Jonathan Yuen | Budget: 1 000 000 SEK

Collaborations

Countries:	Academic institutions:	Other organisations:
- Ethiopia - Kenya - Uganda	- Haramaya University, Dire Dawa, Ethiopia - Makerere University, Kampala, Uganda	- CIP (Centro Internacional de la Papa, International Potato Center), Kenya

Publications

Published in peer reviewed scientific journals	0
Manuscripts for peer reviewed scientific journals	1

Zeleke, D.S., Fininsa, C., Forbes, G.A., and Yuen, J. **Mitochondrial DNA Diversity and Evolutionary Relationships of Some Ethiopian *Phytophthora infestans* isolates and related species**.

Book chapters/conference proceedings	2

Proceedings of the 9th Triennial African Potato Association (APA) conference, Naivasha, Kenya, 2013.

Proceedings of the 10th International Congress of Plant Pathology, Beijing, China, 2013.

Popular science publications	1

CIP Blog - http://www.rtb.cgiar.org/studying-a-new-threat-to-the-potato-farmers-of-east-africa/

Master/Bachelor theses	1

Njoroge, Anne (MSc thesis, 2013 (pending)). **Variability of *Phytophtora infestans* in Uganda and Kenya and its implications to late blight management in potato and tomato**. Dept of Agricultural Production, Makerere University, Uganda.

Pamphlets/teaching material	0

Activities organised

Scientific conferences/workshops	2
Courses/training activities	2
Workshops/courses for end users	0

High value crops and insect pest management in East Africa, *p. 46*

Project leader: Teun Dekker

Budget: 1 000 000 SEK

Collaborations

Countries:	Academic institutions:	Other organisations:
- Ethiopia - Kenya	- University of Addis Ababa, Ethiopia	- Holetta Agricultural Research Center, Ethiopia - Arbaminch Plant Health Clinic, Ethiopia - Upper Awash Agro Industry Enterprise (UAAIE), Ethiopia - *icipe* (International Center of Insect Physiology and Ecology), Kenya

Publications

Published in peer reviewed scientific journals 0

Manuscripts for peer reviewed scientific journals 4

Dejene, T., Karlsson, M., Seyoum, E., Hillbur, Y., and Dekker, T. **Identification of host blends that attract the African invasive fruit fly *Bactrocera invadens* (Diptera: Tephritidae)**.

Karlsson, M.F., Kurabachew, B., Seyoum, E., Hillbur, P., and Hillbur, Y. **Action-based fruit fly learning and management in a diverse agricultural area**.

Mulugeta, T., Dekker, T., Hillbur, Y., Seyoum, E., and Aregay, B. **Responses of parasitoid *Diadegma mollipla* to potato tuber moth infested and non-infested solanaceous plants and perspectives for push-pull intervention in tomato**.

Proffit, M., Hillbur, Y., Axelsson, J., Aregay, B., and Dekker, T. **Enemy free space for the potato tuber moth: parasitoid Diadegma mollipla does not recognize PTM-induced volatiles in tomato**.

Book chapters/conference proceedings 0

Popular science publications 0

Master/Bachelor theses 5

Axelsson, Johan (MSc thesis, 2013). **Tomato: enemy free space for the potato tuber moth in Ethiopia**, Dept of Crop Protection Biology, Swedish University of Agricultural Sciences.

Dejene, T. (MSc thesis, 2012). **Study on the electrophysiological and behavioural responses of the African Invasive Fruit Fly, *Bactrocera invadens* (Diptera: Tephritidae) to semiochemicals**, Addis Ababa University, Ethiopia.

Mekonnen, B. (MSc thesis, 2013). **Electrophysiological responses of *Bactrocera invadens*, Bactrocera olea and *Ceratitis capitata* to head space volatiles of mango and orange fruits**, Addis Ababa University, Ethiopia.

Mersha, M (MSc thesis, 2013). **Dispersal patterns of *Bactrocera invadens* in the terrains of the Southern Rift Valley area of Arbaminch, Ethiopia**, Addis Ababa University, Ethiopia.

Mulugeta, T. (MSc thesis, 2013). **Behavioural response of *Diadegma mollipla*, a parasitoid, to potato tuber moth infested and non-infested different solanaceous species**, Addis Ababa University, Ethiopia.

Pamphlets/teaching materials 1

Activities organised

Scientific conferences/workshops 1

A pan-African workshop on chemical ecology in multilevel management (SEMIO-11) was arranged within the project.

Courses/training activities 0

Workshops/courses for end users 3

Livestock productivity and food security in the rangeland pastoral communities in Uganda, *p. 52*

Project leader: Ewa Wredle | Budget: 3 000 000 SEK

Collaborations

Countries:	Academic institutions:	Other organisations:
- Uganda	- Makerere University, Kampala, Uganda	

Publications

Published in peer reviewed scientific journals	0
Manuscripts for peer reviewed scientific journals	4

Johansson, C., Wredle, E., Katorumunda, S., Mpairwe, D., Sabiiti, E., and Spörndly, E. **Effects of management and season on lactating dairy cows in a semi-arid rangeland environment**.

Johansson, C., Wredle, E., Mpairwe, D., Sabiiti, E., and Spörndly, E. **Effects of management and season on calf growth in a semi-arid rangeland environment**.

Katorumunda, S., Wredle, E., Mpairwe, D., and Sabiiti, E. **Effect of protein supplementation on the performance of Ankole x Friesian crossbred calves grazed on natural pastures in the rangelands of Uganda**.

Tibezinda, M., Mpairwe, D., Sabiiti, E., and Wredle, E. **Assessment of the on-farm feed resources availability and utilisation in the agro-pastoral system od south western Uganda**.

Book chapters/conference proceedings	0
Popular science publications	1

Results of the research were televised on local TV and broadcasted on several radio stations. This had impact on several farmers who were not included in the study, or who lived nearby the study area.

Master/Bachelor/Licentiate theses	2

Johansson, Christina (Licentiate thesis, 2013). **Performance of dairy cows and calves in agro-pastoral production systems**. Dept of Animal Nutrition and Management, Swedish University of Agricultural Sciences.

Nabisubi, Regina (MSc thesis, 2013 (pending)). **Effect of drought on the productivity and persistence of forage plants in Agro-Pastoral systems of Uganda**. Dept of Agricultural Production, Makerere University.

Pamphlets/teaching materials	2

Activities organised

Scientific conferences/workshops	0
Courses/training activities	3
Workshops/courses for end users	1

A workshop, including a field day for farmers and extension officers, was conducted to build farmers capacity in dairy cattle management and feeding. Held in Kazo, Uganda 2012.

Reproductive health management in dairy cows in Uganda, *p.56*

Project leader: Renée Båge | Budget: 1 500 000 SEK

Collaborations

Countries:	Academic institutions:	Other organisations:
- Uganda	- Makerere University, Kampala, Uganda	

Publications

Published in peer reviewed scientific journals	0
Manuscripts for peer reviewed scientific journals	1

Kanyima Mbabazi, B., Ntallaris, T., Owiny, D.O., Båge, R., Magnusson, U., and Nassuna-Musoke, M.G. **Husbandry factors for the resumption of ovarian activity of dairy cows under open and zero-grazing dairy farming production system in urban/peri-urban Kampala, Uganda**.

Book chapters/conference proceedings	2

Proceeding from the 15th International Conference on Production Diseases in Farm Animals, 2013. (two presentations).

Proceedings from the 17th European Society for Domestic Animal Reproduction Conference, Bologna, 2013.

Popular science publications	0
Master/Bachelor theses	1

Eklundh, Camilla (MSc thesis, 2013). **The use of artificial insemination in dairy farms in urban/peri-urban Kampala, Uganda**. Dept of Clinical Sciences, Swedish University of Agricultural Sciences.

- Pamphlets/teaching materials	1

Activities organised

Scientific conferences/workshops	0
Courses/training activities	2

A clinical course in gynecological ultrasound and reproductive health management was held by a Swedish specialist for the academic staff in the Reproduction group at Makerere.

A clinical course in embryo technologies, including theory and practice, was held by Swedish specialists at SLU and at the breeding company Viking Genetics and Nötcenter Viken. The course was attended by the PhD student/lecturer from Makerere.

Workshops/courses for end users	0

Comment: Staff members in the Reproduction group at Makerere University is the target group in our project. Academic teachers and researchers are also involved in herd health extension service and in the education of artificial insemination technicians. Knowledge and capacities achieved during our project has been implemented in their daily work.

Animal genetic resources for improved livestock productivity under harsh environmental conditions, *p. 60*

Project leader: Erling Strandberg

Budget: 1 500 000 SEK

Collaborations

Countries:	Academic institutions:	Other organisations:
- Ethiopia - Kenya		- EIAR (The Ethiopian Institute for Agricultural Research) - ILRI (International Livestock Research Institute) - Ministry of Agriculture, Ethiopia - Ministry of Livestock Development, Kenya

Publications

Published in peer reviewed scientific journals: 1

Zonabend, E., Okeyo, A.M., Ojango, J.M.K., Hoffmann, I., Moyo, S., and Philipsson, J. (2013). **Infrastructure for sustainable use of animal genetic resources in Southern and Eastern Africa**. Animal Genetic Resources.

Manuscripts for peer reviewed scientific journals: 2

Stein, J., Mulatu, W., Ayalew, W., Lemecha, H., Malmfors, B., Dessie, T., Rege, J.E.O., and Philipsson, J. **Production, reproduction and trypanotolerance in four Ethiopian cattle breeds kept on station in a tsetse infested area**.

Zonabend, E., Mirkena, T., Audho, J., Okeyo, A.M., Ojango, J.M.K., Näsholm, A., Malmfors, B., Strandberg, E., and Philipsson, J. **Breeding objectives for red Maasai and Dorper sheep in Kenya - a participatory approach**.

Book chapters/conference proceedings: 1

Proceeding of the Agricultural Research for Development Conference: Innovations and Incentives, Uppsala, Sweden, 2012.

Popular science publications: 0

Master/Bachelor theses: 1

Liljestrand, Josefina (MSc thesis, 2012). **Breeding practices of Red Maasai sheep in Maasai pastoralist communities**. Dept of Animal Breeding and Genetics, Swedish University of Agricultural Sciences.

Pamphlets/teaching materials: 4

Activities organised

Scientific conferences/workshops: 0

Courses/training activities: 2

Two workshops of training with survey enumerators have been carried out besides the continuous training with farmers and enumerators when visiting the farmers for collection of data.

Workshops/courses for end users: 3

Results from the study of trypanotolerance of Ethiopian cattle breeds have been shared with all relevant national stakeholders at a workshop held in Addis Ababa, Ethiopia.

For the Red Maasai studies, progress and results have been shared with farmers and stakeholders at two workshops held in Kenya

Studies on African Swine Fever virus and its genetic variation in different host species..., *p. 64*

Project leader: Mikael Berg

Budget: 1 000 000 SEK

Collaborations

Countries:	Academic institutions:	Other organisations:
- Uganda	- Makerere University, Kampala, Uganda	- Animal Industry and Fisheries, Uganda - ILRI (International Livestock Research Institute) - Ministry of Agriculture, Animal Industry and Fisheries, Uganda - Uganda Wildlife Authority, Uganda

Publications

Published in peer reviewed scientific journals: 4

Blomstrom, A.L., Stahl, K., Masembe, C., Okoth, E., Okurut, A.R., Atmnedi, P., Kemp, S., Bishop, R., Belak, S., and Berg, M. (2012). **Viral metagenomic analysis of bushpigs (*Potamochoerus larvatus*) in Uganda identifies novel variants of Porcine parvovirus 4 and Torque teno sus virus 1 and 2**. Virology journal *9*, 192.

Blomstrom, A.L., Stahl, K., Okurut, A.R., Masembe, C., and Berg, M. (2013). **Genetic characterisation of a porcine bocavirus detected in domestic pigs in Uganda**. Virus genes *47(2)*, 370.

Brink, M., Stahl, K., Masembe, C., Okurut, A.R., Berg, M., and Blomstrom, A.L. (2012). **First time molecular detection and phylogenetic relationships of torque teno sus virus 1 and 2 in domestic pigs in Uganda: further evidence for a global distribution**. Virology journal *9*, 39.

Masembe, C., Michuki, G., Onyango, M., Rumberia, C., Norling, M., Bishop, R.P., Djikeng, A., Kemp, S.J., Orth, A., Skilton, R.A*., et al.* (2012). **Viral metagenomics demonstrates that domestic pigs are a potential reservoir for Ndumu virus**. Virology journal *9*, 218.

Manuscripts for peer reviewed scientific journals: 1

Blomstrom, A.L., Stahl, K., Masembe, C., Okurut, A.R., Atimnedi, P., Kempe, S., Bishop, R., Belak, S., and Berg, M. **Viral metagenomics analysis of soft ticks (*Ornithodoros*) in Uganda reveals a novel RNA virus with distant relationship to hepatitis E virus**.

Book chapters/conference proceedings: 1

Proceedings of the 6th Annual Meeting EPIZONE – Viruses on the move, Brighton, United Kingdom, 2012. (three presentations)

Popular science publications: 0

Master/Bachelor theses: 5

Aliro, Tony (MSc thesis, 2013). **The dynamics of African Swine Fever in a post-conflict area: the case of Gulu district in Northern Uganda**, Makerere University, Uganda.

Brink, Matilda (BSc thesis, 2011). **Porcine viruses in Uganda: a study of TTSuV and PPV4 in wild and domestic pigs**. Dept of Biomedical Sciences and Veterinary Public Health, Swedish University of Agricultural Sciences.

Ndyanabo, Suzan (MSc thesis, 2012). **A longitudinal sudy of ASF in domestic pigs in Masaka and Rakai**, Makerere University, Uganda.

Nyberg, Emilia (BSc thesis, 2011). **Prevalence and genetic characterization of African Swine Fever virus in vectors and domestic pigs in Uganda**. Dept of Biomedical Sciences and Veterinary Public Health, Swedish University of Agricultural Sciences.

Olsson, Jenny (MSc thesis, 2013). **Characterization of novel small porcine DNA viruses**. Dept of Biomedical Sciences and Veterinary Public Health, Swedish University of Agricultural Sciences.

Pamphlets/teaching materials: 4

Activities organised

Scientific conferences/workshops: 1

Courses/training activities: 0

Workshops/courses for end users: 4

Soil and water management in agricultural production – participatory management..., *p. 70*

Project leader: Erik Karltun | Budget: 2 000 000 SEK

Collaborations

Countries:	Academic institutions:	Other organisations:
- Ethiopia	- Addis Ababa University, Ethiopia - Hawassa University, Ethiopia	- Ethiopian Institute for Water Resources (EIWR), Addis Ababa University, Ethiopia

Publications

Published in peer reviewed scientific journals 3

Gebrehiwot, S.G., Bewket, W., Gärdenäs, A., and Bishop, K. (2013a). **Forest cover change over four decades in the Blue Nile Basin, Ethiopia: comparison of three watersheds**. Reg Environ Change, 1-14.

Gebrehiwot, S.G., Gärdenäs, A., Bewket, W., Seibert, J., Ilstedt, U., and Bishop, K. (2013b). **The long-term hydrology of East Africa's water tower: statistical change detection in the watersheds of the Abbay Basin**. Reg Environ Change, 1-11.

Gebrehiwot, S.G., Seibert, J., Gärdenäs, A.I., Mellander, P.-E., and Bishop, K. (2013c). **Hydrological change detection using modeling: Half a century of runoff from four rivers in the Blue Nile Basin**. Water Resources Research *49*, 3842-3851.

Manuscripts for peer reviewed scientific journals 0

Book chapters/conference proceedings 2

Karltun, E., Gichamo, T., Abebe, T., Lemenih, M., Tolera, M., and Chiwona-Karltun, L. (2012). **Participatory reintroduction of *Vicia faba* beans in resource-poor farming systems - adoption of a farmer-led initiative**. In EarthScan (in press)

Proceedings of the: 12th ESSS conference - Soils for sustainable development. Addis Ababa, Ethiopia, 2011.

Popular science publications 0

Master/Bachelor theses 4

Gichamo, Tesfanesh (MSc thesis, 2011). **Dispute or residing together in harmony? Bean cultivation and theft in rural Ethiopia**. Dept of Urban and Rural Development, Swedish University of Agricultural Sciences.

Madalcho, Aklilu Bajigo (MSc thesis, 2012). **The effect of land use change on soil physic-chemical properties over time in Munsea Shashemene, Oromia Region, Ethiopia**, Wondo Genet College of Forestry and Natural Resources, Hawassa, Ethiopia.

Mechi, Atome Abebe (MSc thesis, 2013). **Rural women's livelihood vulnerability to climate change and their adaptation mechanisms: The case of Ada'a woreda, Oromia Region, Ethiopia**. Dept of Geography and Environmental Studies, Addis Ababa University, Ethiopia.

Poultouchidou, Anatoli. (MSc thesis, 2012). **Effects of forest plantations on soil carbon sequestration and farmers' livelihoods - A case study in Ethiopia**. Dept of Soil and Environment, Swedish University of Agricultural Sciences.

Pamphlets/teaching materials 2

The project has printed and distributed two different advisory posters for soil fertility management and compost making translated the local language *oromiffa*

Soil and water management in agricultural production – participatory management..., *continued, p. 70*

Activities organised

Scientific conferences/workshops	2
Workshop: "**Water as the mirror of landscapes: How useful a hypothesis for resource management?**", Uppsala 28-29 March, 2012	
Workshop: "**Agriculture in the face of climate change**", Debre Zeit, Ethiopia, 8-9 November 2012	
Courses/training activities	2
Workshops/courses for end users	1
Stakeholder workshop: "**Making soil fertility last in the highlands of Ethiopia, the case of Arsi Negelle**", combined with field training for farmers workshop in Shashemene, Ethiopia, 19-20 August 2011	

Evaluation of Integrated Soil Fertility Management approaches for improved productivity..., *p. 74*

Project leader: Kristina Röing de Nowina — Budget: 2 000 000 SEK

Collaborations

Countries:	Academic institutions:	Other organisations:
- Kenya	- Moi University, Kenya - Nairobi University, Kenya	- CIAT (Center for Tropical Agriculture), Kenya - IITA (International Institute of Tropical Agriculture)

Publications

Published in peer reviewed scientific journals: 0

Manuscripts for peer reviewed scientific journals: 2

Nambafu, G.N., Onwonga, R.N., Karuku, G., Ariga, E.S., Vanlauwe, B., Obasanjo, P.M., Kimutai, G., and Röing de Nowina, K. **Knowledge, attitude and practice in the control of striga weed in maize by smalholder farmers of western Kenya**.

Röing de Nowina, K., Andrén, O., Vanlauwe, B., Kirchmann, H., and Kätterer, T. **Application of biochar to Humic Ferrasols and Humic Nitisols in Western and Central Kenya - effect on crop yields and nutirent uptake during 10 growing seasons**.

Book chapters/conference proceedings: 3

Proceedings of the International Conference on Integrated Soil Fertility Management in Africa: from Microbes to Markets. Nairobi, Kenya, 2012. (three presentations)

Proceedings of the International Conference on Challenges and Opportunities for Agricultural Intensification of the Humid-Highland Systems of sub-Saharan Africa (CIALCA). Kigali, Rwanda, 2011.

Proceeding of the Agricultural Research for Development Conference: Innovations and Incentives, Uppsala, Sweden, 2012

Popular science publications: 0

Master/Bachelor theses: 6

Casselbrant, Madelene, and Lindqvist Ståhle, Siri. (BSc thesis, 2012). **Demand and perception of fertilizer: among small-holder farmers in Kenya**. Dept of Economics, Swedish University of Agricultural Sciences.

Jönsson, Tina, and Rådman, Mika. (BSc thesis, 2012). **Economic impact of fertilizers and improved seeds among smallholder farming systems in Central and Western Kenya**. Dept of Economics, Swedish University of Agricultural Sciences.

Kimutai, Geoffrey (MSc thesis, 2013). **Low soil fertility and *Striga hermonthica* management using nitrogen fertilizers and host plant resistance in Bondo, Siaya, Vihiga counties**. Dept of Soil Sciences, Moi University, Kenya.

Larsson, Miriam (MSc thesis, 2013). **Soil fertility status and *Striga hermonthica* infestation relationship due to management practices in western Kenya**. Dept of Soil and Environment, Swedish University of Agricultural Sciences.

Nambafu, Godfrey (MSc thesis, 2013). **Efficacy of farmers' soil fertility management practices in the control of *Striga hermonthica*: a case study of the smallholder farmers of western Kenya**. Department of Land Resource Management and Agricultural Technology Nairobi University, Kenya.

Obasanjo, Patrick (MSc thesis, 2013). **Assessing soybean (Glycine-maxima (L) Merill) for managing *Striga hermonthica* and improving soil fertility in western Kenya**. Dept of Soil Sciences, Moi University, Kenya.

Pamphlets/teaching materials: 1

Activities organised

Scientific conferences/workshops: 1

Part in organizing the conference: "**Integrated Soil Fertility Management in Africa: From Microbes to Markets**", October 2012, Nairobi, Kenya.

Courses/training activities: 0

Workshops/courses for end users: 1

Can integration of trees and crops contribute to enhanced agricultural productivity..., *p. 78*

Project leader: Ingrid Öborn | Budget: 2 000 000 SEK

Collaborations

Countries:	Academic institutions:	Other organisations:
- Kenya	- Jomo Kenyatta University of Agriculture and Technology, Kenya	- Vi Agroforestry Programme, Kenya - ICRAF (World Agroforestry Centre), Kenya

Publications

Published in peer reviewed scientific journals 1

Hoang, M.H., Namirembe, S., van Noordwijk, M., Catacutan, D., and Öborn, I. (2013). **Farmer portfolios, strategic diversity management and climate change vulnerability - comparative studies in Vietnam and Kenya**. Climate and Development *Accepted for publication*.

Manuscripts for peer reviewed scientific journals 8

Dahlin, A.S., Fransson, P., Alvum-Toll, K., Ström, K., Ofori, D., and Jamnadass, R. **Examination of mycorrhizal associations and soil requirements of *Allanblackia stuhlmannii* – a tree under current domestication**.

Nyaga, J., Barrios, E., Muthuri, C.W., Öborn, I., Matiru, V.N., and Sinclair, F.L. **Implications of small scale farming on tree diversity in maize-based agricultural landscape of Western Kenya**.

Nyaga, J., Jefwa, J.M., Muthuri, C.W., Okoth, S.A., Matiru, V.N., and Wachira, P.M. **Effect of soil fertility amedments on arbuscular mycorrhizal fungi abundance and diversity in Kenyan highlands**.

Nyaga, J., Jefwa, J.M., Muthuri, C.W., Okoth, S.A., Matiru, V.N., and Wachira, P.M. **Influence of soil fertility amendment practices on ex-situ utilisation of indigenous arbuscular mycorrhizal fungi and performance of maize and common bean under varying phosphorus levels**.

Nyberg, Y., Öborn, I., Jonsson, M., Laszlo Ambjörnsson, E., and Sinclair, F.L. **Identification of adaptation and coping measures to rainfall variability in two contrasting areas**.

Perez Teran, A.S., Dumas-Johansen, M.K., Catacutan, D., Nguyen, Q.H., Hoang, M.H., Enjebo, I., Öborn, L., Gathenya, J.M., Mwangi, P.N., and Öborn, I. **Climate, water and livelihoods: adaptation strategies in the humid highlands of Kenya**.

Rusinamhodzi, L., Dahlin, A.S., Corbeels, M. **Intensification options for the extensive farming systems of central Mozambique: application of the NUANCES framework**.

Musee, C., Wachiye, E., Nyberg, Y., I., O., and et.al. **Sustainable Agricultural Land Management Practices: What does it mean for farm and household performance (maize productivity, savings, food and firewood security)? Evaluation of four years experiences from the Kenya Agricultural Carbon project in two districts of W Kenya. Report Vi Agroforestry Programme**.

Can integration of trees and crops contribute to enhanced agricultural productivity...,*continued, p. 78*

Book chapters/conference proceedings	4

Van Noordwijk M, Hoang MH, Neufeldt H, Öborn I, Yatich T, eds. 2011. **How trees and people can co-adapt to climate change: reducing vulnerability through multifunctional agroforestry landscapes**. Nairobi: World Agroforestry Centre (ICRAF)

Proceedings of the International Conference on Integrated Soil Fertility Management in Africa: from Microbes to Markets. Nairobi, Kenya, 2012. (three presentations)

Proceeding of the Agricultural Research for Development Conference: Innovations and Incentives, Uppsala, Sweden, 2012. (two presentations).

Proceedings of the International Conference on Challenges and Opportunities for Agricultural Intensification of the Humid-Highland Systems of sub-Saharan Africa (CIALCA). Kigali, Rwanda, 2011.

Popular science publications	0
Master/Bachelor theses	7

Alvum-Toll, Kajsa (MSc thesis, 2013). **Allanblackia - a tree under current domestication: what are the soil requirements?** Dept of Soil and Environment, Swedish University of Agricultural Sciences.

Berntsson, Sabina, and Winberg, Josefine (BSc thesis, 2013). **The influence of water availability on land cover and tree functionality in smallholder farmer settlements. A minor field study in Trans Nzoia County, Kenya**. Dept of Physical Geography and Ecosystem Science, Lund University, Sweden.

Blokland, Marjolene (MSc thesis, 2013 (pending)). **Effects of trees and livestock on aggregate stability on smallholder farms in Western Kenya**, Vrije University, The Netherlands.

Cornelissen, Paul (MSc thesis, 2013 (pending)). **Farmers perspective in comparison with scientific soil research in Trans Nzoia district Western Kenya**, Vrije University, The Netherlands.

Enjebo, Ida, and Öborn, Lisa (Minor Field Study no.165, 2012). **A Farming System Analysis on the Slope of Mount Kenya. A study of how water resources and land use are affected by climate variability in two areas in Embu District, Kenya**. Committee for Tropical Ecology, Uppsala University.

Fogelberg, Johan (MSc thesis, 2013 (pending)). **The roles of trees for water infiltration on farms in Trans Nzoia disstrict in western Kenya**, Dept of Biosystems and Technology, Swedish University of Agricultural Sciences.

Ström, Helena (MSc thesis, 2013). **Allanblackia – a tree crop under current domestication: What are the important symbionts?** Dept of Forest Mycology and Plant Pathology, Swedish University of Agricultural Sciences.

Pamphlets/teaching materials	0

Activities organised

Scientific conferences/workshops	1

Co-organizers of the *Integrated Soil Fertility Management Africa* Conference in Nairobi, Kenya, October 2012

Courses/training activities	1
Workshops/courses for end users	2

Workshop: *Training of Trainers on Sustainable Agriculture Land Use Management and Food Security*, Kisumu, Kenya, November 12th –15th, 2012.

Workshop: *Training of Farmers on Productive and Sustainable farming in Trans Nzoia*, Kitale, Kenya, April 22-25, 2013.

Soil carbon, water infiltration and root competition: implications for management..., *p. 84*

Project leader: Gert Nyberg

Budget: 1 000 000 SEK

Collaborations

Countries:	Academic institutions:	Other organisations:
- Kenya - Ethiopia - Burkina Faso	- Hawassa University, Ethiopia - Jomo Kenyatta University of Agriculture and Technology, Kenya	- CIAT (International Centre for Tropical Agriculture), Kenya - ICRAF (World Agroforestry Center), Kenya - ILRI (International Livestock Research Institute), Kenya - INERA (Institut de l'Environnement et des Recherches Agricoles), Burkina Faso

Publications

Published in peer reviewed scientific journals: 1

Nyberg, G., Tobella, A.B., Kinyangi, J., and Ilstedt, U. (2012). **Soil property changes over a 120-yr chronosequence from forest to agriculture in western Kenya**. Hydrol Earth Syst Sc *16*, 2085-2094.

Manuscripts for peer reviewed scientific journals: 0

Book chapters/conference proceedings: 3

Proceedings of the first African IUFRO-FORNESSA Regional Congress and ITTO/AFF Forest Policy Day - Forest and Trees Serving the Peole of Africa and in the World. Nairobi, Kenya, 2012.

Proceeding of the Agricultural Research for Development Conference: Innovations and Incentives, Uppsala, Sweden, 2012.

Proceedings of the International Conference on Challenges and Opportunities for Agricultural Intensification of the Humid-Highland Systems of sub-Saharan Africa (CIALCA). Kigali, Rwanda, 2011.

Popular science publications: 0

Master/Bachelor theses: 0

Pamphlets/teaching materials: 0

Activities organised

Scientific conferences/workshops: 0

Courses/training activities: 0

Workshops/courses for end users: 2

Two seminars with local farmers were conducted in Ochoria and Nyando for dissemination and discussion of research results with 15-30 farmers at each seminar.

Gender and REDD+. Global instruments and changing environmental governance, *p. 90*

Project leader: Seema Arora Jonsson | Budget: 1 000 000 SEK

Collaborations

Countries:	Academic institutions:	Other organisations:
- Burkina Faso - Sweden - Tanzania	- Gotenburg University, Sweden - Sokoine University of Agriculture, Tanzania - University of Ouagadougou, Burkina Faso	

Publications

Published in peer reviewed scientific journals	0
Manuscripts for peer reviewed scientific journals	2

Arora Jonsson, S., Westholm, L., Temu, B. **Climate instruments and global governance: new public spaces and notions of citizenship**.

Westholm, L., Arora Jonsson, S. **Defining solutions, finding problems: Deforestation, gender and REDD+ in Burkina Faso**.

Book chapters/conference proceedings	0
Popular science publications	0
Master/Bachelor theses	2

Temu, Beatus (MSc thesis, 2012). **Carbon business scenarios and communities' choices under REDD+ in Lindi Rural district, Tanzania**, Sokoine University of Agriculture, Tanzania.

Yeboah, Yaw (MSc thesis, 2013). **Gendering the REDD+ policy process in Ghana**. Dept of Urban and Rural Development, Swedish University of Agricultural Sciences.

Pamphlets/teaching materials	0

Activities organised

Scientific conferences/workshops	1

Co-organizer of the **IUFRO, International Union of Forest Research Organizations' Gender and Forestry Conference, *Environmental governance and four decades of gender research: Where do we stand?*** 27 - 29 November, 2012, Wondo Genet Forestry College, Ethiopia

Courses/training activities	1
Workshops/courses for end users	0

Identification of cassava varieties meeting farmers' preferences for participatory breeding, *p. 96*

Project leader: Anna Westerberg	Budget: 1 500 000 SEK

Collaborations

Countries:	Academic institutions:	Other organisations:
- Vietnam		- Plant Resource Centre, Vietnam Academy of Agricultural Sciences, Vietnam

Publications

Published in peer reviewed scientific journals	0
Manuscripts for peer reviewed scientific journals	3

Lundquist, P.-O., Le, Q., and Westerbergh, A. **Mycorrhiza diversity in cassava farmers' fields in Vietnam**.

Westerbergh, A., and Chiwona-Karltun, L. **Comparison of genetic diversity and farmers' management of cassava in Southeast Asia and East Africa – two regions with different cassava breeding history**.

Westerbergh, A., Hoang, N., Tran, D., Ngo, Q., Le, T., Vu, L., and Lundquist, P.-O. **Interdisciplinary studies combining farmer interviews and genetic analysis revealed variation in cassava genetic diversity among farmers' field in northern, central and southern Vietnam**.

Book chapters/conference proceedings	1

Proceeding of the Agricultural Research for Development Conference: Innovations and Incentives, Uppsala, Sweden, 2012.

Popular science publications	0
Master/Bachelor theses	0
Pamphlets/teaching materials	0

Activities organised

Scientific conferences/workshops	0
Courses/training activities	0
Workshops/courses for end users	0

Expanding cassava production and accelerating commercialisation in southern Africa.., *p. 100*

Project leader: Linley Chiwona-Karltun | Budget: 1 500 000 SEK

Collaborations

Countries:	Academic institutions:	Other organisations:
- Denmark - Ghana - Malawi - Moçambique - Sweden - The Netherlands - Uganda - USA - Zambia	- Lund University, Sweden - Michigan State University, USA - University of Copenhagen, Denmark - University of Ghana, Ghana - University of Zambia - Uppsala University, Sweden	- CMRTE (Chinangwandi Mbatata Roots & Tubers Association), Malawi - IAAM (Instituto de Investigação Agrária de Mozambique), Mozambique - NARO (National Agricultural Research Organisation, Uganda - Programme against Malnutrition, Zambia - Rural Women Foundation, The Netherlands - SARRNET (Southern Africa Root Crops Research Network), Malawi

Publications

Published in peer reviewed scientific journals 3

Afoakwa, E.O., Asiedu, C., Budu, A.S., Chiwona-Karltun, L., and Nyirenda, D.B. (2012). **Chemical composition and cyanogenic potential of traditional and high yielding CMD resistant cassava (*Manihot esculenta* Crantz) varieties**. International Food Research Journal *19*, 175-181.

Afoakwa, E.O., Budu, A.S., Asiedu, C., Chiwona-Karltun, L., Nyirenda, D.B. (2011) **Application of Multivariate Techniques for Characterizing Composition of Starches and Sugars in Six High Yielding CMD Resistant Cassava (*Manihot esculenta* Crantz) Varieties**. J Nutr Food Sci 1:111

Haggblade, S., Andersson Djurfeldt, A., Nyrienda, D.B., Bergman Lodin, J., Brimer, L., Chiona, M., Chitundu, M., Chiwona-Karltun, L., Cuambe, C., Dolislager, M*., et al.* (2012). **Cassava commercialization in southeastern Africa**. Agribusiness in Developing and Emerging Economies *2*, 4-40.

Manuscripts for peer reviewed scientific journals 3

Bergman Lodin, J., Andersson Djurfeldt, A., Nyrienda, D.B., Brimer, L., Haggblade, S., Jirström, M., Ntawuruhunga, P., and Chiwona-Karltun, L. **Tipping the scales in favour of cassava - revisiting policies to shape agricultural investments**.

Chiwona-Karltun, L., Nyirenda, D.B., Mwasa, C.N., Kongor, J.E., Brimer, L., Haggblade, S., and Afoakwa, E.O. **Chemical composition and cyanogenic glykoside potentials of different cassava (*Manihot exculenta* Crantz) varieties from southeastern African regions**.

Vuong, T., Ntawuruhunga, P., and Chiwona-Karltun, L. **Responding to cyclic food crisis with cassava - local perspectives on implementation and sustainability**.

Book chapters/conference proceedings 2

Proceedings of the Second Scientific Conference of the Global Cassava Partnership for the 21st Century. Kampala, Uganda, 2012. (11 presentations).

The Nordic Africa Days 2012. Reykjavik, Iceland 2012.

Expanding cassava production and accelerating commercialization in southern Africa..,*continued, p. 100*

Popular science publications	4

Linley Chiwona-Karltun, Blessings Chinsinga, Olof Hesslemark, David Mkwambisi and Inge Gerremo (2013 forthcoming). **Is the Malawi subsidy programme designed to facilitate sustainable agrarian transformation?** www.naiforum.org

Linley Chiwona-Karltun, Inge Gerremo, Agnes Andersson Djurfeldt & Magnus Jirström (2013). **Kassava kan stärka kvinnors roll i det afrikanska jordbruket**. Värmlands Folkblad

Linley Chiwona-Karltun & Inge Gerremo 2013. **Stärka kvinnors roll i det afrikanska jordbruket**. Biståndsdebatt

Linley Chiwona-Karltun & Inge Gerremo 2013. **Stärka kvinnors roll i det afrikanska jordbruket**. Omvärlden 2

Master/Bachelor theses	3

Budu, Agnes Simpson (MSc thesis, 2012). **Chemical composition and cyanogenic potential of traditional and high yielding CMD resistant cassava (*Manihot esculenta* Crantz) varieties**, University of Ghana, Ghana.

Mwasa, Mwansa Nkonkola (MSc thesis, 2013). **Chemical composition and cyanogenic glycoside potentials of different cassava (*Manihot esculenta* Crantz) varieties from southeastern African regions**, University of Zambia, Zambia.

Vuong, Thao Thi Phuong (MSc thesis, 2012). **Farmers' perceptions of the "Unleashing the Power of Cassava in Africa in Response to the Food Crisis" (UPoCA) project: Experiences from Malawi**. Department of Earth Sciences, Uppsala University.

Pamphlets/teaching materials	1

Activities organised

Scientific conferences/workshops	4

Workshop: **Inception research project programme**, held at University of Zambia, Zambia

Workshop: **Cassava varietal understanding with farmers,** held at the Chinangwa ndi mbatata roots and tubers association (CMRTE), Malawi

Workshop: **Cassava transformation in Southeastern Africa (CATISA)** held at the National Agricultural Research Organisation (NARO), Uganda

Workshop: **Fast-tracking cassava transformation in southeastern Africa to improve food security and livelihoods (FAST-Tracking-CATISA),** held at Instituto de Investigação Agrária de Moçambique (IIAM), Mozambique

Courses/training activities	2
Workshops/courses for end users	2

Plant breeding and genetic resources – collaborations between SLU, South Africa..., *p. 108*

Project leader: Eva Johansson | Budget: 3 000 000 SEK

Collaborations

Countries:	Academic institutions:	Other organisations:
- Ethiopia - South Africa - Zambia - Zimbabwe	- Stellenbosch University, South Africa - University of the Free State, South Africa - Wollo University, Ethiopia	- Zambia Agriculture Research Institute, Zambia - Seed Services, Department of Research and Specialist Services, Zimbabwe

Publications

Published in peer reviewed scientific journals: 0

Manuscripts for peer reviewed scientific journals: 8

Andersson, S., Jönsson, E., Labuschagne, M., van Bijon, A., and Johansson, E. **Protein composition in South African sorghum**.

Dhar Burra, D., Bengtsson, T., Moshaib, L., Weighill, D., Hedley, P., Jacobson, D., Liljeroth, E., Andreasson, E., and Alexandersson, E. **Time course analysis of leaf transcriptome after phosphite treatment for induced defence responses in *Solanum tubersoum* (cv. Des)**.

Hailu, F., Johansson, E., and Persson Hovmalm, H. **Assessment of genetic erosion: a case study of tetraploid wheat from Ethiopia and Spain**.

Hailu, F., Johansson, E., Persson Hovmalm, H., van Bijon, A., and Labuschagne, M. **Quality assessment with HPLC in released varieties of tetraploid wheat from Ethiopia and Spain**.

Hailu, F., Johansson, E., Persson Hovmalm, H., van Bijon, A., and Labuschagne, M. **Regional patterns of quality of landraces of durum wheat from Ethiopia with HPLC**.

Labuschagne, M., Mkhatywa, N., Wentzel, B., Johansson, E., and van Bijon, A. **Tocochromanol content, and protein and baking quality of white flour of South African wheat cultivars**.

Mkhatywa, N., Johansson, E., Labuschagne, M., and Andersson, S. **Influence of genotype, location and storage on tocopherols content in South African wheat**.

Nguni, D., Andersson, S., van Bijon, A., and Labuschagne, M. **Evaluation of sorghum lines for grain yield, protein and micronutrient content**.

Book chapters/conference proceedings: 0

Popular science publications: 0

Master/Bachelor theses: 4

Geiger, Armin (MSc thesis, 2013 (pending)). **Transcriptomic and Proteomic analysis of plants and microbes**, Stellenbosch University, South Africa.

Jönsson, Emma (MSc thesis, 2013 (pending)). **Evaluation in quality parameters in South African sorghum**. Dept of Plant Breeding, Swedish University of Agricultural Sciences.

Mkhatywa, Nomcebo (MSc thesis, 2013). **Baking quality and nutritional value in South African wheat**. Dept of Crop Science, University of the Free State, South Africa.

Weighill, Debbie (BSc thesis, 2013). **Parallelization of OrthoMCL and phylogenomic analysis of gene families**, Stellenbosch University, South Africa.

Pamphlets/teaching materials: 0

Activities organised

Scientific conferences/workshops: 0

Courses/training activities: 1

Development of a joint PhD-course in Fieldomics, which was carried out with students from involved countries.

Workshops/courses for end users: 0

Chemical ecology in integrated control of insect pests in southern Africa, *p. 114*

Project leader: Teun Dekker

Budget: 1 000 000 SEK

Collaborations

Countries:	Academic institutions:	Other organisations:
- Kenya - South Africa	- University of Kwazulu Natal, South Africa	- *icipe* (International Center of Insect Physiology and Ecology), Kenya - South African Sugercane Research Institute (SASRI), South Africa

Publications

Published in peer reviewed scientific journals	0
Manuscripts for peer reviewed scientific journals	2

Karlsson, M.F., Kurabachew, B., Seyoum, E., Hillbur, P., and Hillbur, Y. **Action-based fruit fly learning and management in a diverse agricultural area**.

Okoth, C., Rutherford, S., Juergensen, A., Dekker, T., and Conlong, D. **Parasitoid recognition of host-induced cues in sugarcane and sedge**.

Book chapters/conference proceedings	0
Popular science publications	0
Master/Bachelor theses	0
Pamphlets/teaching material	0

Activities organised

Scientific conferences/workshops	1

A pan-African workshop on chemical ecology in multilevel management (SEMIO-11) was arranged within the project.

Courses/training activities	0
Workshops/courses for end users	0

Biodiversity and ecosystem services: interaction and utility, *p. 118*

Project leader: Barbara Ekbom | Budget: 1 000 000 SEK

Collaborations

Countries:	Academic institutions:	Other organisations:
- South Africa - Sweden	- Lund University, Sweden - Stellenbosch University, South Africa - University of the Free State, South Africa - University of Pretoria, South Africa	- South African Sugarcane Research Institute (SASRI), South Africa - The Forestry and Agricultural Biotechnology Institute (FABI), University of Pretoria, South Africa

Publications

Published in peer reviewed scientific journals	0
Manuscripts for peer reviewed scientific journals	0
Book chapters/conference proceedings	0
Popular science publications	0
Master/Bachelor theses	0
Pamphlets/teaching materials	0

Activities organised

Scientific conferences/workshops	1
Workshop: ***Invasive forest threats: Future research and management opportunities***, University of Pretoria, South Africa.	
Courses/training activities	1
PhD course: **Biological control as a method to control pests**, Stellenbosch University, South Africa.	
Workshops/courses for end users	0

Genetic resources and plant breeding – collaborations between SLU and Central Asia, *p. 124*

Project leader: Larisa Gustavsson | Budget: 2 375 000 SEK

Collaborations

Countries:	Academic institutions:	Other organisations:
- Kenya - Kyrgyzstan - Mexico - Syria - Tajikistan - USA	- Kyrgyz Agrarian University, Kyrgyzstan - Tajik Agrarian University, Tajikistan - University of Minnesota	- Kenyan Agricultural Research Institute (KARI), Kenya - CIMMYT, International Maize and Wheat Improvement Centre, Mexico - ICARDA (International Centre for Agricultural Research in Dry Areas), Syria

Publications

Published in peer reviewed scientific journals	0
Manuscripts for peer reviewed scientific journals	7

Andersson, S.C., Johansson, E., Baum, M., Rihawi, F., BDabous, A., and El Bouhssini, M. **New resistance sources to Russian wheat aphid (*Diuraphis noxia,* Kurdjumov) in Swedish wheat (*Triticum asetivum*) substitutions and translocations with rye (*Secale cereale*) and *Leymus mollis***.

Andersson, S.C., Johansson, E., Bonnett, D., Baum, M., Rihawi, F., and El Bouhssini, M. **New resistance sources to Hessian fly (*Mayetiola destructor*) in Swedish winter wheat (*Triticum aestivum*) substitutions and translocations with rye (*Secale cereale*)**.

Husenov, B., Makhkamov, M., Garkava-Gustavsson, L., Merker, A., Muminjanov, H., and Johansson, E. **Variation of protein composition in Tajik wheat breeding materials: implications in breeding for bread making quality**.

Rahmatov, M., Andersson, S.C., Garkava-Gustavsson, L., and Johansson, E. **Stem rust adult plant and seedling resistances in 1BL.1RS and 2RL.2BS double wheat-rye translocation lines**.

Torutaeva, E., Zborowska, A., Ortiz, R., Turgunbaev, K., and Garkava-Gustavsson, L. **Are Kyrgyz apples unique?**

Usubaliev, B., Brantestam, A., Salomon, B., Bumane, S., Garkava-Gustavsson, L., and von Bothmer, R. **Agronomic performance of spring barley cultivars under different eco-environmental conditions**.

Usubaliev, B., Brantestam, A., Salomon, B., Garkava-Gustavsson, L., and von Bothmer, R. **Genetic relationships among the spring barley cultivars from Kyrgyzstan and North European and West-central Asian barley as indicated by microsatellites**.

Book chapters/conference proceedings	3

Proceedings of the EUCARPIA Genetic Resources Section Meeting – Pre-breeding – fishing in the gene pool. Alnarp, Sweden, 2013.

Proceedings of Technical Workshop Borlaug Global Rust Initiative. St. Paul, Minnesota, USA, 2012. (two presentations)

Proceedings of the International Wheat Stripe Rust Symposium. Aleppo, Syria, 2011. (two presentations

Popular science publications	0
Master/Bachelor theses	0
Pamphlets/teaching materials	0

Activities organised

Scientific conferences/workshops	1
Courses/training activities	3
Workshops/courses for end users	0

Improved animal health systems for control of zoonoses, *p. 130*

Project leader: Ulf Magnusson | Budget: 2 375 000 SEK

Collaborations

Countries:	Academic institutions:	Other organisations:
- Tajikistan	- Tajik Agrarian University, Tajikistan	

Publications

Published in peer reviewed scientific journals: 0

Manuscripts for peer reviewed scientific journals: 2

Lindahl, E., Sattorov, N., Boqvist, S., and Magnusson, U. **A study of knowledge, attitudes and practices relating to brucellosis among dairy farmers in an urban and peri-urban area of Tajikistan**.

Lindahl, E., Sattorov, N., Boqvist, S., Sattori, I., and Magnusson, U. **Seropositivity for Brucella and associated factors in dairy cows in urban and peri-urban small scale farming in Tajikistan**.

Book chapters/conference proceedings: 3

Proceedings of the 14th AITVM (Association of Institutions for Tropical Veterinary Medicine) Conference. Johannesburg, South Africa, 2013.

Proceedings of the 17th Conference of the European Society for Domestic Animal Reproduction. Bologna, Italy, 2013.

Proceeding of the Agricultural Research for Development Conference: Scales and Diversity, Uppsala, Sweden, 2011

Popular science publications: 0

Master/Bachelor theses: 2

Grahn, Cecilia (MSc thesis, 2013). **Brucellosis in small ruminants: an investigation of knowledge, attitude and practices in peri-urban farming around the region of Dushanbe, Tajikistan**. Dept of Clinical Sciences, Swedish University of Agricultural Sciences.

Ljung, Isabel (MSc thesis, 2013). **Brucellosis in small ruminants: a seroprevalence study in peri-urban farming around the region of Dushanbe, Tajikistan**. Dept of Clinical Sciences, Swedish University of Agricultural Sciences.

Pamphlets/teaching materials: 1

"TAU-SLU research on zoonotic diseases in periurban animal farming in district of republican subordination"

Activities organised

Scientific conferences/workshops: 0

Courses/training activities: 1

Course: *Control of Infectious Diseases in Livestock,* December 2011, SLU, Sweden

Workshops/courses for end users: 1

Workshop: Presentation of the outcomes of the project, Tajik Agrarian University, April 2013, Tajikistan.

Conference photos

Some of the participants of the SLU Africa Food Security Research Symposium, Kampala 4-6 December 2012.

Some of the participants of the SLU Global Food Security Research Symposium, SLU Uppsala, Sweden, 12-13 June 2013.

The SLU Global Food Security Research and Education Program 2010-2013 – a Swedish Government Initiative

In October 2010 the Swedish Ministry of Foreign Affairs allocated specific funding to the Swedish University of Agricultural Sciences (SLU) for work to support global food security. The allocation was made with the long-term aim to reduce hunger and malnutrition by supporting the improvement of agricultural productivity through research and higher education. SLU's mission was to engage with institutions particularly in Africa, conduct high quality collaborative research and enhance the capacity development of partner institutions. Priority research areas included plant breeding, farming systems, animal health and disease control. In this report, results generated from projects within the program are presented.

The **Swedish Unversity of Agricultural Sciences (SLU)** has core competence within the agricultural sciences, including forestry and veterinary sciences. The areas of expertise cover urgent global issues such as food production, energy supply, climate change, biodiversity conservation and control of infectious diseases in animal and man.

To strengthen SLU's involvement in issues related to improving productivity in agriculture, food security and sustainable livelihood in low-income countries, the university has established the programme **Agricultural Sciences for Global Development, (SLU Global)**. The programme's mission is to coordinate and visualize SLU's competence in research, education and expert council within the frame of the Swedish Policy for Global Development.

www.slu.se/slu-global

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