Consortium for Research in East African Tropical Ecosystems

Climate Change, Ecological Interactions, Land Use Management, and Social Impacts

Botanical Garden, Maseno University, February 19, 2014

Le Savanna Country Hotel, Kisumu, February 20, 2014

Abstracts of Presentations

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The Intention of the Maseno / University of Bayreuth CREATE Activity

Dr. Dennis Otieno, Department of Plant Ecology, University of Bayreuth
Dennis.Otieno@uni-bayreuth.de

Anthropogenically-induced climate and land use changes are negatively impacting natural and man-made ecosystems through modified radiation input, temperature and precipitation regimes, with negative consequences on human well-being. Alleviating the impacts of anthropogenically-based climate forcing and the sustainable management of our ecosystems and natural resources demand new approaches in research, decision-making and management. The diversity and complexity of environmental challenges require multi-disciplinary approaches that provide complementary knowledge and expertise through collaborative research aimed at common solutions. Collaboration among researchers and institutions through consortium building will enhance competency in the production, analyses and distribution of vital knowledge on global change issues and in relation to ecosystem management. Via the CREATE (Consortium for Research in East African Tropical Ecosystems) platform for information exchange, we intend to promote a broad and new type of cooperation in the wise use of natural resources that will support human well-being in East Africa during the next decades. The aims are to: (1) enhance research capacity through complementary knowledge and expertise, and by providing access to equipment and instrumentation, (2) improve research capabilities through increased focus, new skills and techniques and (3) enhance institutional complementarities. In this effort, we view Maseno University as advantageously located to provide leadership and focus for knowledge synthesis in East Africa, that will simultaneously provide 1) scientific results on complex ecosystem and landscape processes, 2) information to advise stakeholders about sustainable long-term investments, and 3) the means for linking scientific evaluations with regional agency management efforts. The success hinges on governance and leadership that will facilitate and

enable coalition building. This goes hand in hand with proactive strategies that promote the expansion of research capacities.

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ICSU/IGBP Program on Ecosystem Change and Society – PECS: An Important Potential for Information Exchange with Respect to the Efforts of CREATE

Prof. John Tenhunen, Dept. of Plant Ecology, University of Bayreuth
John.Tenhunen@uni-bayreuth.de

The late Nobel Peace Prize winner Dr. Wangari Maathai was a person able to perceive the linkages between politics, economics, ecosystem science, global change and human well-being. In the conclusion of her book published in 2009 summarizing a vision for future advancement in Africa, she made the following statement:

"This struggle to preserve what they have and hold it close to them is one that all Africans – indeed, all people – should engage in. Because if the soil is denuded and the waters are polluted, the air is poisoned, wildlife is lost and the mineral riches are mined and sold beyond the continent, nothing will be left that we can call our own. And when we have nothing to call our own, we have nothing to reflect back to us who we truly are."

Wangari Maathai: "The Challenge for Africa"

The newly initiated global change programs of "Future Earth" (http://www.icsu.org/future-earth) and Ecosystem Change and Society (http://www.pecs-science.org/) expand on the vision of Dr. Maathai and others, working "to integrate research on the stewardship of social–ecological systems and to break down barriers that have impeded understanding of social-ecological transformations. The Programme on Ecosystem Change and Society (PECS) is a new initiative within the ICSU global change programs that aims to integrate research on the stewardship of social—ecological systems, the services they generate and the relationships among natural capital, human wellbeing, livelihoods, inequality and poverty. The vision of PECS is a world where human actions have transformed to achieve sustainable stewardship of social—ecological systems. The goal of PECS is to generate the scientific and policy-relevant knowledge of social—ecological dynamics needed to enable such a shift, including mitigation of poverty."

(from http://www.stockholmresilience.org/21/research/research-programmes /pecs.html)

The long-term goals of CREATE based on "bottom-up" cooperation among scientists and scientific organizations overlap with those of PECS, and focus on promoting sustainable acquisition of ecosystem services, their economic gains, and supporting resource management under global change. Therefore, contact and cooperation with the PECS should be fostered, and examples of ways in which this could be promoted are given.

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Achieving Positive Orientation to Environmental Problem Solving in Kenya

Prof. Omondi Ahawo, Department of Sociology and Anthropology,
Maseno University, Kenya, ndagwe@yahoo.com

This article argues for a reorientation of the approaches to environmental problems from a scientific basis to a social, people oriented basis. Using examples from a research project in Western Kenya, (Maseno and Nagoya Universities), the article argues for a pro-people approach to tackle specific environmental problems. The paper argues for need to re-conceptualize the "farmer" and to differentiate people engaged in traditional socio-cultural activities from people in "farming business". There is also need to include policy professionals in the process of engaging the "natives", the researchers and the policy makers in solving local environmental problems. This will also involve a change in the "extension worker" policy from being reactive to pro-active. Since environmental issues are best understood in local contexts, Kenya's devolved constitution presents the best scenario for achieving positive examples for achieving positive orientation to environmental problem solving in Africa.

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Critical Social Interactions That Promote Preservation of Landscape Function

Mr. Maurice Wanjela, Kipsaina Crane and Wetlands Conservation Group, Kesogon
maurice_wanjala@yahoo.com

The Kipsaina Crane and Wetlands Conservation Group has worked since 1990 to preserve ecosystems critical to the functional integrity of Saiwa National Park and breeding sites of the grey crowned crane. Land use change, especially in upstream locations, occurred due to anthropogenic activities related to the pursuit of individual private interests, and this change in turn resulted in degradation of wetlands and has threatened important aspects of biodiversity. The solution to such problems, before irreversible damage occurs, depends on community-based approaches where local stakeholders are informed and convinced about potential undesirable losses in ecosystem services; services that are part of their heritage. The presentation discusses experiences with local stakeholders, steps in communication that have led to change, and alternatives that have been accepted and have permitted wetland rehabilitation. Future resource management depends strongly on this type of acceptance and support by local stakeholders or ecosystem service end-users. The end-users must be tied into resource management networks.

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Agricultural Technologies and Their Role in Providing Agro-Ecosystem Services in Selected Sites of Kenya

Dr. Immaculate Maina, KARI-NPBRC, Njoro
immaculate.n.maina@gmail.com

In Kenya, small scale farmers, through their stewardship of diverse farming systems, produce and maintain many desirable ecosystem services in agricultural landscapes. Farmers' management practices influence productivity and status of the environment. Beyond crop production, management of agricultural landscapes leads to reductions in poverty, improved household health, and sustainable use of natural resources. National Research and Development (R&D) institutions such as the Kenya Agricultural Research Institute (KARI) and their partners work with farmers in enhancing their capacities to produce and maintain desired agro-ecosystem services. This paper highlights some of the agricultural technologies and their role in providing agro-ecosystem services in selected sites of Kenya. It presents the work carried out by KARI with funding from the International Development Research Centre (IDRC) and the Ford Foundation. These partners continue to implement research and development (R&D) projects with a focus on research technologies that foster sound environmental management outcomes and long-term economic development with benefits to local communities. Over the past three years, the agricultural technologies promoted in Eastern and Central Kenya, through this collaboration, yielded many socio-ecological related outputs and outcomes. Integrated Soil Fertility Management (ISFM) technologies addressed the problem of soil fertility degradation which remains the major biophysical cause of declining per capita crop production in Kenya. The use of tied ridges and contour furrows for water harvesting as well as organic and inorganic fertilizers for external soil amendment yielded positive ecosystem services in the form of on-farm nutrient replenishment and higher crop yields. Promoting traditional crops, also called "orphan crops" using the agri-food systems approach, among smallholder farmers in diverse agro-ecosystems enhanced nutrition, productivity, biological integrity and climate adaptability while maintaining diversity, lessening the impacts of disease or pest outbreak and providing nutritional and health benefits. Agricultural technologies of orphan crops such as cowpeas, green grams, sorghum, lab lab, banana, sun flower and passion fruit are closely linked to diverse socio-ecological systems such as increased participation and enhanced learning and farmer experimentation. In Kenya, implementation of agricultural technologies occurs within complex agro-ecological systems and diverse socio-ecological systems which are important for smallholder agricultural production to achieve multi-functionality from agricultural landscapes.

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Tropical Deforestation and Reforestation Dynamics: Quantifying Gains and Losses in Ecosystem Services

Dr. Thanh Nguyen and Mr. Cosmas Combat Lambini,
BayCEER, University of Bayreuth
Thanh.Nguyen@uni-bayreuth.de

Tropical forests provide a variety of ecosystem services essential to the society and human well-being. However, tropical forests continue to degrade globally, with negative consequences for environmental sustainability and forest-dependent human communities. Despite signs of forest recovery in a few countries, the rate of tropical deforestation remains alarmingly high. Furthermore, the area of degraded tropical forests is substantial and, thus, reforestation is important to support people and reduce pressures for additional deforestation. It is believed that reforestation provides one of the solutions to the current problem of forest loss and its consequences. Our presentation provides an overview on (1) tropical deforestation, (2) the major drivers of tropical deforestation, (3) the impacts of tropical deforestation on ecosystem services, and (4) the main responses to tropical deforestation with a focus on reforestation efforts in some developing countries, leading to potential gains in ecosystem services. Due to different local and regional settings of socio-ecological systems, tropical deforestation and reforestation as well as their effects are also different, and there is still insufficient knowledge and empirical evidence useful to the formulation of future policy responses. This indicates a need for more efforts devoted to these issues.

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Patterns of Landuse and Landcover Change in Western Kenya

Mr. Joseph Okotto Okotto, Manager of Planning Research and Special Projects, LBDA
Dr. Mike Norton-Griffiths, Senior Research Fellow, ICRAF
Mr. Harvey Herr, Spatial Data Analyst, ICRAF, jokotto@hotmail.com

Data from FEWS (Famine Early Warning System) show significant trends in both precipitation and temperature across western Kenya over the last 30 years. A comparison between high resolution sample aerial photographs taken in 1983 across western Kenya with similar photography taken in December 2012 has shown significant changes in landcover and landuse. Specifically, agriculture has expanded in both extent (650,000 hectares of new cultivation) and intensity (>50% of the land is now cultivated at >50% intensity); tree cover has shown a modest loss from 20.01 ha km^{-2} in 1983 to 18.22 ha km^{-2} in 2012; while there has been a substantial investment in agroforestry of 115,000 hectares, from a cover density of 7.75

ha km^{-2} in 1983 to 11.04 ha km^{-2} today. Major infrastructural components, especially road networks, land tenure and population growth all have important influences on the rates of change in land use and land cover.

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Rice promotion in Kenya: Management of water and nitrogen nutrition for productivity

Prof. J.C. Onyango, Department of Botany, Maseno University, Kenya
jconyango@yahoo.com

Rice is a crop that is currently feeding over half of the world's over 7.138 billion population and doubles both as subsistence and export cereal. Rice production is increasingly becoming a key issue in cereal growth and development in the Sub-Saharan Africa region. The increasing consumer preference has pushed rice into the list of the most important crops that require concerted effort in production. Farmers in most Sub-Saharan Africa produced enough food commodities for the continent's populations up to the 1960s' at the time of independence for most countries. After attaining independence from the imperial powers the African population started growing at a faster rate than food production. By 1980s' most countries were pleading to the developed world for food aids. The major development problem in Africa is infrastructure, that is roads, dams, electricity and communication. These are areas which were ignored by the colonial powers as opposed to the development pattern in Asia and Latin America before the de-colonization era in those regions. Strong economies and high quality of life are an integral part of good and responsive governance in terms of economic and development policies and this has eluded the majority of African governments over the years. It is important to take note that perfection is a peacock that the academics chase and never catch. As researchers and intellectual think tank we must undertake our share of the responsibility apart from advocating academic freedom.

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Cultivation of Bambara groundnuts in Western Kenya as a food and cash crop

Dr. Darius O. Andika, School of Agricultural and Food Sciences,
Jaramogi Oginga Odinga University of Science and Technology
oandika@yahoo.co.uk

Bambara groundnuts (*Vigna subterranea*) is an Indigenous African crop that has been cultivated in Africa for centuries. It's a highly nutritious plant which plays a crucial role in people's diets and is currently grown throughout Africa. It has been reported as one of the indigenous food crops found in Western Kenya that has a potential for reducing food and

nutritional insecurity. Despite its usefulness in terms of nutrition and improvement of soil fertility, it remains one of the crops neglected by the scientific community and is commonly referred to as "poor man's crop". The main objective of the study was to evaluate the role of Bambara groundnuts (*Vigna subterranea*) in cropping systems in Western Kenya and determine its potential as a cash crop. Structured questionnaires and observation checklists were used to obtain household information on the role and potential of Bambara groundnuts in household food security. Field experiments were conducted both on farmers' fields and on-station to determine the role of Bambara groundnuts in cropping systems. The Bambara crop is mainly grown during the short rainy season between September and December. Its production area per house hold has been diminishing over the years since the late 1980s, until recently it has been picked up as a short rain season crop. Over 75% of the farmers grow Bambara groundnuts as an intercrop with cereals, mainly maize and to a little extent sorghum and millet. The knowledge of the crop remains low and marketing opportunities of the crop need to be developed.

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Potential of Bamboo for Farming, Environmental Conservation and Poverty Alleviation in South Nyanza, Kenya

Prof. G.W. Netondo, Department of Botany, Maseno University, Kenya,
godfreynetondo@yahoo.co.ke

Bamboo as a grass is a versatile raw material, which can be used for food, building materials, artifacts and raw materials for production of pulp and paper products. Unlike most other forest tree species bamboos are fast growing and capable of annual returns. Given its unrivalled position in terms of diversity, distribution and uses, coupled with the vital role it plays in the rural economies of several countries around the world, bamboo has emerged in recent years as potentially the most important non-wood forest resource. In Kenya, there has been a shift from the indigenous to exotic bamboo partly due to the government ban and largely due to the fact that within the last 15-20 years, significant developments have taken place with the recognition that the once minor and non-wood resources of the forest come within the remit of the forester and that they contribute greatly in reduction of rural livelihoods vulnerability. Bamboo industry, largely featured as non-labour intensive, low to medium investment, and simple in technology and equipment, is making important contribution in providing food, housing and income generation for 2.2 billion people in the world. As the market for environment friendly green bamboo products is growing, it is estimated that the world bamboo market would grow from the present size of US $ 8.5 billion to over US $ 20 billion by 2015. In the mid-1990s, the bamboo industry in Kenya was worth 10 billion shillings annually. This potential needs to be exploited through bamboo

farming. Over 20 exotic bamboo species have been introduced into Kenya by KEFRI during the last two decades using demonstration plots established at various ecological zones as part of bamboo promotion strategy, largely through the support of IDRC. However, these species are yet to be widely planted by farmers. In the past about ten years a project funded by IDRC was used to promote bamboo farming as an alternative to tobacco farming in South Nyanza region. This was meant to provide livelihood alternatives to tobacco production in Suba, Kuria, Homa Bay and Migori Districts. The paradigm shift from tobacco to bamboo farming was touted as a panacea to conservation of tree resource, eradication of myriad tobacco related social problems as well as provision of alternative and sustainable source of livelihoods to the South Nyanza populace. This was partly based on the fact that bamboo is a fast growing, renewable, wide spread, low cost, environmental enhancing resource with great potential to improve poverty alleviation and economic development. This paper shares the experiences, successes/achievements and challenges encountered during the period when bamboo was introduced and provides a platform for possible wide scale cultivation of bamboo in Lambwe region.

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Black Tea Yield and Quality Responses of Clone Bbk 35 Tea to Nitrogen Fertilizer Application Rates and Harvesting Intervals in the Lake Victoria Basin of Kenya

Prof. Philip Okinda Owuor, Department of Chemistry, Maseno University, Maseno, Kenya, pokindao@gmail.com

Tea is an economic crop in the Lake Victoria basin of East Africa, earning high foreign exchange and creating employment opportunities especially in the rural poor regions where economic activities are rare. It is grown under varying environments causing differences in growth rates, yields, metabolites responsible for quality and black tea quality. However, agronomic recommendations are uniform throughout the region despite these differences. It is not known if the uniform inputs are optimal for production of high yields and quality in different locations. Most trials that have been conducted in different regions have used different cultivars making it difficult to isolate the contribution of the geographical area of production on the responses observed. Nitrogenous fertiliser use and harvesting are the most costly agronomic inputs and their incorrect uses reduce yields and black tea quality. Trials using clone BBK 35 were conducted at Timbilil, Changoi, Kipkebe, and Sotik Highlands within the Lake Victoria basin in Kenya to relate yields and black tea quality responses of the cultivar to locations of growth, nitrogenous fertiliser rates and plucking intervals. Yields and black tea quality significantly ($P \leq 0.05$) varied with the environment. Similarly, rates and extents of yields and quality responses varied with locality, demonstrating that despite uniform agronomic inputs, different locations need different levels of inputs for optimal

economic returns. Black tea quality declined with high rates of nitrogenous fertiliser and long plucking intervals. There was yield increase at Changoi and decrease at Sotik Highlands with long plucking intervals. It is concluded that region specific agronomic recommendations are necessary to realise high yields and quality black teas. However, low rates of nitrogenous fertilisers of about 100 kg N ha^{-1} $year^{-1}$ and short plucking intervals produced high quality black teas.

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Strategic Repositioning of Under-Utilized and Neglected Species (NUS) for Food Security, Nutrition, Health and Economic Development in Kenya

Prof. Mary Abukutsa, Department of Horticulture,
Jomo Kenyatta University of Agriculture and Technology, Kenya
abukutsa.mary@gmail.com

Nearly half of the world's population live on less than two dollars a day and half the population in Africa live on less than a dollar a day. Poverty manifests itself in malnutrition, diseases and poor health. Ninety per cent (90%) of the calories in human diet come from 15 crops and 60% from three crops, wheat, rice and maize. Agro-biodiversity remains unexploited. There is need to strategically reposition neglected and underutilized species (NUS) for food security and improved livelihoods. This paper highlights the advantages, constraints and global strategies and initiatives in repositioning NUS for food security and improving livelihoods of the vulnerable groups in Africa in general and in Kenya in particular. The main advantages of NUS include resilience to climate change, minimize risks of crop loss and have competitive advantage with regard to nutrition and health benefits. Major constraints of NUS include neglect, inadequate awareness, lack of quality seeds and poor policy framework. Repositioning strategies and initiatives include those from GFAR as a coordinating agent. These include Mung bean in Asia, Maca in Peru, Bamboo in China , Quinoa in Peru and African indigenous vegetables in Kenya. Strategic repositioning of NUS will contribute to food security, nutrition, health and economic development in Kenya and Africa at large.

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Standard Assessment of GHG Mitigation Potentials and Livelihoods in Smallholder Systems: the SAMPLES Project

Dr. Klaus Butterbach-Bahl, ILRI Nairobi and KIT Garmisch-Partenkirchen,
Dr. Mariana Rufino, CIFOR, Nairobi, Dr. Todd Rosenstock, ICRAF, Nairobi,
Dr. David Pelster, ILRI, Nairobi
Klaus.Butterbach-Bahl@kit.edu

Smallholder agriculture provides food and income to millions of farmers from the developing world. Little is known about the environmental impact and here specifically on the greenhouse gas (GHG) footprint of this agriculture. So far the few studies on GHG mitigation potential have not been linked to likely effects on people's livelihoods. Studying smallholder agriculture is a challenge because farming takes place in fragmented and diverse landscapes. Even more challenging is the identification of feasible mitigation options. Mitigation practices only become options for poor farmers if they comply with their own livelihood goals, without affecting the production of their land, and its income generating capacity.
The objective of our work is to develop low-cost methods to quantify GHG emissions and to identify mitigation options for smallholders at whole-farm and landscape levels. To finally allow up-scaling of findings we stratify landscapes to identify units which are sampled to study the diversity of farming livelihoods and practices. As study area the Nyando plot, a CCAFS site, representing a 10 km x 10 km landscape section close to Kisumu, has been selected. This plot represents a cross section of typical land uses and topography as found in Western Kenya, including sections with highlands with e.g. tea cropping and lowlands, where maize/bean cropping dominates. Parameters being targeted include productivity, economic outputs, GHG emissions, and their social and cultural importance for the farming families. We calculate tradeoffs across these dimensions to identify mitigation options. Results are communicated using participatory methods, which allow up-scaling using spatial modeling socially acceptable mitigation options that bring benefits at whole farm and landscape levels.

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Phytomedicines: A Regional Approach to Development of Chemotherapeutic Drugs and Empowerment of Local Communities in The Lake Victoria Basin of East Africa

Prof. Philip Aduma, School of Public Health and Community Development (ESPUDEC),
Maseno University Kenya, ragenaduma@gmail.com

The Lake Victoria basin (LVB) of East Africa covers several districts and counties in the five partner states of the East African Community. These states are Burundi, Kenya, Rwanda, Tanzania and Uganda. Problems facing the multiethnic communities of the Lake Victoria basin include poor economic status aggravated by a vicious cycle of rampant poverty, climate change

variability, malnutrition and devastation caused by acute and/or chronic debilitating diseases such as HIV/AIDS and cancer. More than 80% of the infectious and non-infectious diseases occur amongst the working age group of 25-49 years. The income and productivity loss due to disease burden is alarming. HIV/AIDS and cancer for example rank as some of the most important diseases facing the communities of the region. Highly active antiretroviral therapies (HAART) and conventional antibiotics coupled with behavior change campaigns have been significant in reducing prevalence rates of the diseases in most parts of the basin. This however is being threatened by looming reduction in national supply of HAART, increased frequency of appearance of mutant viruses with altered sensitivity to HAART, appearance of drug resistant *Mycobacterium tuberculosis* and lack of understanding of risk factors contributing to infectious and non-infectious diseases as well as potential toxicities of drugs used in combination chemotherapy. This paper recognizes that phytomedicines could provide a credible alternative or complementary therapy in the management of some of these diseases. However, development of these to chemotherapeutic drugs depends on scientific evidence of efficacy and safety. It also requires a continued supply of plant materials for drug development as well as long term measures on sustainable utilization in the face of climate change vulnerability. In this paper, data on validation of efficacy and safety of medicinal plant extracts as well as approaches to the use of medicinal biodiversity as an engine for health care provision, sustainable livelihoods and economic empowerment of local communities in the LVB are presented. Further to this, in the face of ecological degradation and increased vulnerability to climate change risks, this paper addresses the question of which adaptation and coping mechanisms should be put in place to increase medicinal plants and other vegetation cover so as to ensure sustainable utilization of the biodiversity. A multi-country multi-disciplinary approach is also discussed.

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Development and Promotion of Monosex (Male) *Tilapia* Technologies for Enhanced Farmed *Tilapia* Production: Contributing to Food Security and the Conservation of Lake Victoria

Prof. Eliud N. Waindi and Dr. Paul O. Angienda, Department of Zoology, Maseno University, Kenya, enwaindi@yahoo.com

Nile tilapia (*Oreochromis niloticus*) is a popular farmed fish due to its ecological versatility, its economic importance, and ease of breeding in captivity without complex hatchery equipment or hormonal induction of spawning. Hence, it can be bred year round in the tropics. In the Lake region, there is a high potential for a viable tilapia farming at both commercial and subsistence levels. According Kenya government National Fisheries (NF) Policy and Aquaculture (AQ) Policy documents (2011), the country's aquaculture potential amounts to 1.4

billion hectares of fish farming area, with the capacity to produce 11 million tons worth well over KSh 50 billion annually. This potential has not been realized due to number of challenges plaguing this sub-sector. Some are related to policy and legal framework while others are related to on-the-field production of aquaculture fish, i.e. directly affecting the fish farmers. We address the latter. Two major problems in tilapia farming, mentioned in most tilapia aquaculture forums, are the lack of affordable quality fish seed and fish feeds. In relation to tilapia seed (fingerlings), the basic problem is that in a mixed sex culture tilapia breeds prolifically, thereby overpopulating the pond with undersized fish that are unsatisfactory for tilapia breeder striving to grow fish for local market or, more so, for export. One way of intervention is the use of monosex male fingerlings, preferred over monosex female, because males attain larger market sizes faster than females. Several methods are being used to develop monosex male tilapia, including the use of hormones and heat treatment, in which higher temperatures favor sex reversal towards males. Heat treatment technology is safe and is easily adaptable and adoptable. In our current research, we have been able to adapt the heat treatment method to a Lake Victoria Nile tilapia population, attaining a laboratory result ratio of 86.31% males with accompanying fry survival of 65.25%. Preliminary studies on the genetic basis of heat induced sex determination in Nile tilapia elucidated the influence of sex linked SSRs on sex determination by predicting hormones and transcription factors expressed in sex reversed individuals. Moreover, population genetic studies based on microsatellite and mitochondria DNA markers, revealed four distinct populations of Nile tilapia within the Kenyan side of the LVR that could serve as potential for all-male tilapia seed production. While the adoption phase with selected outreach fish farmers is still on, some preliminary results show a modest growth improvement on part of the heat treated fish. In this paper we present the in-lab and outreach results. We also attempt to relate successful fish farming in the region to enhanced food security and conservation of the Lake Victoria region ecosystem.

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Climate Data, Crop Models and Farmers: Understanding Climatic Risks before Discussing Climate Change

Prof. David Stern, Maseno University
volloholic@hotmail.com

This presentation will focus on describing a CCAFS (Climate Change in Agriculture and Food Security) project currently ongoing at Maseno University relating to climate information services. The projects investigate what climate information can be communicated to farmers and how it can help them in their decision making. This starts by presenting historical climatic records to farmers and getting them to calculate risk corresponding to success or failure of certain crops. The process of farmers engaging with data in this way often

leads to a lot of excitement about what can be learnt from data, this is harnessed by providing opportunities for farmers to collect data from their own farm, and potentially even carry out their own experiments. The project then attempts to use the farmer data in crop modelling to explore possible management options with farmers before the season and discuss the outputs with them at the end of the season.

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Impacts of Agricultural Expansion on Natural Ecosystems of Lambwe Valley

Dr. George K' Otuto, School of Agriculture and Food Security, Maseno University
kotutg@yahoo.com

The increasing demand for land for agricultural production to support the growing human population in sub-Saharan Africa has led to an increased conversion of natural savannah ecosystems into agro-ecosystems, particularly croplands and grazing fields. The resultant agro-ecosystems are structurally different and must be equally functionally different from the natural savannah ecosystems. To date, little information exists on how the transformation of natural savanna into agro-ecosystems affects processes such as carbon dioxide (CO_2) exchange, C storage and ecosystem productivity, which are key ecosystem services derived from the savannah. To ensure continued supply of such services and to ensure the well-being of resident human populations, it is imperative that the natural and man-made savannah ecosystems are sustainably managed based on sound scientific principles. Field studies were conducted in the moist savannah of Ruma, Lambwe valley, Kenya in 2008 and 2009 to determine the impact of savanna conversion on ecosystem's productivity, CO_2 exchange and C storage of the herbaceous layer. The studied key variables included inclusion and exclusion of grazing and inclusion or exclusion of maize production. The main parameters measured included gravimetric soil water content (SWC), soil temperature (T_{soil}), total soil and plant nitrogen (N) and C, aboveground biomass, net ecosystem CO_2 exchange (NEE), ecosystem respiration (R_{eco}) and gross primary production (GPP). These parameters were measured on regular monthly intervals. Ecosystem productivity and C fluxes significantly varied seasonally and spatially among the land use plots. The abandoned croplands, after growing maize, were occupied by different plant species from those in the natural savannah, ungrazed savannah and the soils displayed lower soil C stocks. Grazed plots, despite having lower aboveground biomass, GPP and NEE, demonstrated higher productive efficiency (GPP and NEE per unit gram of biomass), implying that complete removal of grazing may lower the ecosystem's productivity in the long run. The management practices considered in our study altered ecosystem CO_2 exchange and productivity through their effects on soil moisture, which was the main driver of ecosystem processes in the herbaceous layer.

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Impacts of Land Use on Soil Properties of Lambwe Valley

Dr. Sebastian Arnhold, Dept. of Soil Physics, University of Bayreuth
Dr. Dennis Otieno, Dept. of Plant Ecology, University of Bayreuth
Prof. Bernd Huwe, Dept. of Soil Physics, University of Bayreuth
sebastian.arnhold@uni-bayreuth.de

Geology, terrain, and climatic factors control the physical and chemical characteristics of soils and their ecological functions, for example their suitability for plant growth. The soil landscape of the Lambwe Valley has been described by the Exploratory Soil Map of Kenya from 1980 as dominated by deep, poorly drained clay soils, such as *Vertisols* and *Solonetz* formed from sediments. Volcanic mountain slopes at the northwest boundary of the valley were characterized by shallow, moderately to well drained *Regosols* or *Luvisols*. However, local variations in topography and land use patterns created by agricultural activities and livestock grazing can influence the variability of soil properties within those groups and change their physical and chemical characteristics. Aim of this study was to describe the variability of soil properties in the upper part of the Lambwe Valley along a transect from the mountain slopes covered with forest and grazing areas down to the plains dominated by agriculture and grassland. Along this transect, we analyzed five soil profiles with respect to their physical properties (texture, coarse fragments, bulk density, and hydraulic parameters), their root densities and distribution, and the contents of carbon and nitrogen. An additional profile was analyzed within a fenced area at the mountain foot slope alongside the transect in order to investigate differences between grazing and non-grazing management. We found strong variations in the textural composition within soil profiles at the mountain slopes with increasing proportions of volcanic gravel and blocky rock material with depth, but a strong enrichment of clay in the subsoil compared to topsoil layers. The enrichment of clay was associated with increasing bulk densities, lower hydraulic conductivity and plant available water. With decreasing slope steepness, rock fragments and subsoil clay contents became smaller, and the plain areas in the valley showed relatively homogeneous textural compositions over their entire profiles. Soils at the foot slopes and in the valley were strongly influenced by agricultural activities. We found loose soil material in the plowed topsoil layers followed by a relatively dense compacted subsurface layer resulting in a strong decline in hydraulic conductivity. Deep soil layers, however, showed lower bulk densities and indicated increasing hydraulic conductivities with depth. As we expected, root densities, carbon, and nitrogen contents were highest in the topsoil at the forested mountain slope and foot slope grazing areas and relatively low in the agriculturally dominated plains. The comparison of the grazing and non-grazing profiles showed no significant differences in soil texture and only slight variations in bulk densities, hydraulic conductivity, and carbon contents. The major differences were found in root density and distribution. Whereas the grazing profile showed a large concentration of fine roots in the top soil, indicating a dense grass cover, the non-grazing profile had a higher number of coarse roots in subsoil layers from developing shrubs and trees. Our results indicate that the geological background and topography were the major controlling factors for soil properties in the Lambwe Valley, but land cover and agricultural activities affected nutrient distribution and soil structure, especially in topsoil layers.

Exclusion of grazing, however, seems to have only marginal impacts on soil properties in this study, but may show long-term effects in the future by developing complex systems of plant roots and soil fauna.

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GIS Application to Relate Movement of Savanna Animals to Forage Production

Mr. Luke Lukaria, Ruma National Park, Kenya Wildlife Services
luke.lukaria@gmail.com

Many ecological factors determine the distribution of herbivores in an ecosystem, such as intra- and interspecific competition, landscape type, water sources, seasonality or facilitation between, grass species, fiber content of the grasses, mineral concentrations determined by grass species richness and biomass. Browse availability and suitability is also a factor that affects movement of herbivores. Knowledge on distribution of herbivores in the park is very useful to the management for the abatement of land degradation, fire management, carrying capacity, and reintroduction of more herbivores, tourism circuits, security operations and production of spatial maps for marketing. Movement of animals is continuously recorded in Ruma National Park. The GIS correlates spatial distribution to forage and biomass production in Ruma National Park. The GIS application was preferred to other modes of data analysis and presentation as it both locates and provides the visual aspects of the subject being studied. This provides an easier interpretation of the information to anyone as it requires basic education to interpret and implement. We started with utilizing the already existing monitoring infrastructure to operate the system. There was an addition of only a GPS and a data sheet to enter points of all the sightings including the illegal activities in the Park. The patrol teams carry out the patrol activities every day and a lot of data are generated which are brought later to the data collection centre for cleaning and entry into the database. On one hand, there is the Management Information System database in which the data are stored for reference, sharing with other data bases, and a central depository point of data and information generation. On the other hand, the data are stored in a Map Source Geo-database to enhance data cleaning, manipulation and isolation in case that the main database encounters a problem. The MIST database provides geospatial location of the animals depending on the stipulated duration that displays GIS information using its ArcGis component. It also produces charts and reports concerning the location and the numbers of the animals using its logic components. Biomass production was calculated using 9 permanent sample plots from where grass clipping was sun-dried and biomass determined. Browse availability (BA) and suitability was estimated using potential ecological carrying capacity on rapid visual black rhino browse availability technique developed by Adcock 2005. Availability was estimated to be 16.46% of which, 84.02% had good to medium food suitability for black rhino and other

browsers, giving a Good/Medium Suitability score (BA score) of 13.84%. However, the potential to hold animal numbers can be adversely affected by lack of a comprehensive habitat management and effective control or eradication of tsetse flies. The park, forest, woodland and grassland boundaries shape files were made so as to determine the location of the animal at any time of purposive requirement. The GIS application is also the best to represent information to senior managers who would not be in a position to traverse the fields during monitoring as they can visualize 2–dimensional vector data representing the management requirements as at that time. It also stores spatial data, represents reality through spatial data layers and provides tools for interactive query and analysis of spatial data for overlay and modeling.

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Selection of Provenances of High Value Agro-forestry Trees for Western Kenyan Farmlands

Prof. Barack O. Owuor, Dept. of Applied Plant Sciences, Maseno University, Kenya.
bowuor4@yahoo.com

Plus tree selection within *Sesbania sesban* L trees on farms in western Kenya enabled identification of superior provenances for pole and other multi-purpose products. This mass selection with progeny testing method though originally applied by forest tree breeders has the advantage of rapid provenance improvement with significant selection progress in a matter of 1 to 2 years, a feat that is particularly appealing and needs adaptation for improvement of other high value tree crops in agro-forestry systems. Mango, *Mangifera indica*, is popular in Western Kenya and provenances of various cultivars which include Ngoe, Boribo Apple and Kent among others exist in farmlands. The provenances of these cultivars exhibit tremendous phenotypic variability. This variability provides an opportunity for quick provenance selection and establishment of plus tree selection orchards for sources of scion wood for high value tree nurseries in the various counties in Western Kenya. Such an initiative provides an appropriate response to a felt need currently expressed by various agricultural development plans being rolled out by the recently established county governments especially for agro-ecologies in Western Kenya

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A Synthetic Overview of Land Degradation, Sustainable Land Management, and Dryland Development in Kenya via a Social-Economic-Environmental Framework

Prof. James F. Reynolds
Nicholas School of the Environment, Duke University, Durham, USA
School of Life Sciences, Lanzhou University, Lanzhou, CHINA
james.f.reynolds@duke.edu

Abstract

As evident from the diverse studies and on-going activities presented in this CREATE workshop, the concepts of *land degradation* and *sustainability* do not lend themselves to easy quantification. Land degradation is usually a slow, continuous process and the accompanying changes (ecological, biogeochemical, hydrological) may not result in an immediate reduction or loss of biological or economic productivity. Secondly, each smallholder has a unique set of coupled human (H)-environmental (E) interactions so the drivers and consequences of land degradation vary from location to location (and change over time and spatial scales). Lastly, there are countless *indirect factors* (national economic policies, international trade) that interact with localized *direct factors* (precipitation, soil fertility, cultivation practices, livestock grazing, etc.), all of which leads to a multi-faceted mix of nonlinear H-E interactions that are difficult to understand and generalize. For these reasons, achieving sustainable land management (SLM) is often an abstract and elusive goal. The issues facing Kenyan smallholders are characteristic of the ones the UN Convention on Combating Desertification (UNCCD) has identified as key. However, there is no formal international science program[1] to guide policy-makers and scientists in tackling these complex problems. I will describe ARID*net,* an international initiative on global desertification that emphasizes the inter-dependencies of H-E systems. ARID*net* (Assessment, Research, and Integration of Desertification research network) evolved from the pressing need for new and creative interdisciplinary approaches to address the global problem of land degradation and SLM, as well as for new thinking that transcends regional and disciplinary concerns. ARID*net* is a loosely-organized consortium of researchers that seek to cultivate: (i) international cooperation between smallholders and scientists to develop practical, field-level SLM practices; and (ii) to use the concepts, experiences, and applications of its participants to support on-going international discussions on SLM and land degradation. The Drylands Development Paradigm (DDP), which consists of five principles, is used as the integrating framework to build such cooperation and to identify potential solutions and opportunities.

[1]Similar to the UNFCCC, which has the IPCC. UNFCCC: United Nations Framework Convention on Climate Change [http://goo.gl/dKqAAm]; IPCC: Intergovernmental Panel on Climate Change; [http://www.ipcc.ch/]