3RD ANNUAL PROJECT MEETING, 2014
icipe Duduville Campus, Nairobi, Kenya
Monday 24 - Tuesday 25 March, 2014

Book of Abstracts and Meeting Programme
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The Climate Change Impacts on Ecosystem Services and Food Security in Eastern Africa (CHIESA) is a four-year research and development project aimed at increasing knowledge on the impacts of climate change on ecosystem services in the Eastern Afromontane Biodiversity Hotspot (EABH).

CHIESA is funded by the Ministry for Foreign Affairs of Finland, and coordinated by the International Centre of Insect Physiology and Ecology (icipe) in Nairobi, Kenya. Through research and training, CHIESA will build the capacity of research communities, extension officers and decision makers in environmental research, as well as disseminate adaptation strategies in regard to climate change. The general areas for environmental research are in agriculture, hydrology, ecology and geoinformatics.

CHIESA activities focus on three mountain ecosystems in Eastern Africa, namely Mt. Kilimanjaro in Tanzania, the Taita Hills in Kenya and Jimma Highlands in Ethiopia. The project consortium monitors weather, detects land use/land cover change, and studies biophysical and socio-economical factors affecting crop yields and food security.

The project also builds the climate change adaptation capacity of East African research institutions, stakeholder organizations and decision-makers through research collaboration and training.

Together with local communities, the project will develop, test and disseminate climate change adaptation tools, options and strategies at the farm level. Further, CHIESA provides researcher training for staff members of the stakeholder organizations, enhances monitoring and prediction facilities by installing Automatic Weather Stations, and disseminates scientific outputs to various actors from farmers to policy-makers.
Dear Participant of the 3rd Annual CHIESA Project Meeting,

The International Centre of Insect Physiology and Ecology (icipe), in collaboration with the lead partners, University of Dar es Salaam, Sokoine University of Agriculture, University of Helsinki and University of York, have implemented the Climate Change Impacts on Ecosystem Services and Food Security in Eastern Africa Project in the selected highland and mountain ecosystems in Ethiopia, Kenya and Tanzania for over three years now.

The project has worked closely with different local, national and regional stakeholder organisations to meet its objectives of filling gaps in knowledge on the impacts of climate variability and change as well as land-use and land-cover change on sensitive and unique montane ecosystems, their services and food security.

One of the main goals is to ensure that the public and private sectors are adequately informed and have enhanced capacity for adaptation to climate change. Thus the focus of the 3rd Annual CHIESA Project Meeting is on Climate Change Adaptation.

A recent technical report on Africa’s Adaptation Gap by UNEP (2013) indicates that the continent will be facing huge economical challenges when adapting to the increasing annual average temperatures towards the end of this century. Agricultural productivity, water availability, human health and many other critical components of human livelihood will be affected by the projected changes. However, it is important to assess, identify and understand which of the projected changes and impacts are driven by climatic factors and which by non-climatic factors in order to design and develop the right interventions for adaptation and to be able to avoid maladaptation.

Establishing a correlation between the different project components and their findings calls for a trans-disciplinary approach; one which allows the CHIESA project scientists and scholars to move across the boundaries of their own discipline, to inform one another’s work. The complexity of the interrelated factors needs to be captured and transferred into concrete action plans for climate change adaptation at different levels.

This Annual Meeting brings together ministries, research organisations, NGOs, CBOs and other stakeholders with a tremendous amount of expertise and various fields of knowledge. I would like to use this wonderful opportunity to invite you to actively contribute to the discussions, give feedback and share your experiences and good practices with the CHIESA Project teams and other participants.

On behalf of icipe and the CHIESA Project, I would like to warmly welcome you to the annual meeting organised at the Duduville Campus in Nairobi, Kenya.

Dr Tino Johansson
Coordinator, CHIESA Project
Distinguished Ambassador, Permanent Secretaries, Professors, ladies and gentlemen, climate variability and climate change are projected to bring considerable challenges to agricultural production, water security, health and infrastructure in Africa. Majority of its people earn a living from rain-fed agriculture and livestock rearing which make them sensitive and exposed to the short, medium and long-term impacts of global warming. Functional and resilient agro-ecosystems are key to sustainable livelihoods and adaptation to climate variability and change.

Understanding the eco-physiological responses of plant and insect species to rising annual average air temperatures and changes in relative humidity, as well as the delicate relationship between natural enemies and their insect pest hosts will help to maintain critical ecosystem services such as pollination and pest control, and consequently support rural livelihoods and food security.

Established in 1970, the International Centre of Insect Physiology and Ecology (icipe) is a 40+ years old pan-African research and development centre headquartered in Nairobi, Kenya and carries out research on arthropods to develop techniques and approaches to help communities manage and prevent insect-driven risks, such as crop damage and vector-borne diseases. The population dynamics of insects are influenced by their adaptive behaviours and thermal tolerance. Species adaptive traits, for example tolerance of temperature variances and extremes, affect their demographic dynamics and shapes species distribution under the changing climate.

However, it is important to emphasise that climate-driven factors are not the only ones compromising food security and livelihoods in Africa. Many human-induced changes in our environment, such as habitat fragmentation through deforestation and expansion of agricultural activities, and intensive use of pesticides, threaten biodiversity and reduce the quantity and quality of available ecosystem services.

The Climate Change Impacts on Ecosystem Services and Food Security in Eastern Africa (CHIESA) Project, funded by the Ministry for Foreign Affairs of Finland, is one of icipe’s flagship projects addressing the knowledge gaps on the afore-mentioned issues. The project also contributes widely to the capacity building of young African scholars to address climate-related research questions. In total, the CHIESA Project supports 15 doctoral and 17 masters degree scholars from the stakeholder organisations. Hundreds of farmers within the three research areas in Kenya, Tanzania and Ethiopia have already participated in project activities, a trend that will grow towards the end of the project when community-based action plans for climate change adaptation are developed.

We are grateful to the Government of Finland for their support of this important regional research and development project, which icipe implements in collaboration with other partner and stakeholder organisations in eastern Africa, Finland and the United Kingdom. On behalf of icipe, I wish you a successful project meeting and a pleasant stay here at the Duduville Campus in Nairobi, Kenya.

Dr Segenet Kelemu
Director General, icipe
Ladies and gentlemen, it is my pleasure to join and welcome you during this occasion of CHIESA’s 3rd Annual Project Meeting.

The Climate Change Impacts on Ecosystem Services and Food Security in Eastern Africa Project, CHIESA, aims to fill critical gaps in knowledge related to natural and anthropogenic factors affecting climate variability, climate change and land use/cover change with impacts on ecosystem services and food security. As you are aware the Ministry for Foreign Affairs Finland has been financing this programme since 2011.

1. Finland’s Development Policy

Finland development policy rates climate change highly in its agenda. Climate sustainability is one of its three critical cross-cutting objectives, the others being gender equality and reduction of inequality. Finland recognizes that vulnerability to impacts of climate variability and climate change are most felt by the poor in developing countries. In its own development cooperation therefore, Finland aims to, as much as is feasible, achieve carbon neutrality. It is also keen on strategic climate impacts assessment, to ensure that the impacts of development cooperation on climate are assessed comprehensively ex-ante. Ex-ante prevention can reduce the extent of damage and can save lives. Strengthening the capacity of developing countries’ own administrations to prepare for natural disasters and investing in the disaster risk reduction is a necessity.

In an endeavor to reduce social and physical vulnerability to climate change, Finland aims to integrate adaptation measures into its development cooperation. Particular attention is paid to the roles of women, children and indigenous peoples in adapting to climate change. Finland also supports long-term measures that reduce the vulnerability of people and communities to natural disasters. This requires substantial improvement of ex-ante preparedness in Finland’s development cooperation programmes and projects.

2. What we are doing in Kenya

Finland focuses on four priority areas of development policy and development cooperation: a democratic and accountable society that promotes human rights; an inclusive green economy that promotes employment; sustainable management of natural resources and environment protection; and human development. In Kenya, three programmes demonstrate how mainstreaming of climate sustainability has been embraced in our bilateral programmes.

The PALWECO programme (Programme for Agriculture and Livelihoods in Western Communities) contributes to building adaptive capacity of farming communities in Busia County through support to three elements of adaptive capacity: diversification, storage and market access. Our
support to the forestry sector through the programme *Miti Mingi Maisha Bora* enhances capacity of Kenya Forest Service in forest resources assessment as a critical ingredient in establishing accurate information on forest carbon stocks and changes in carbon stocks. Its focus on improving livelihoods in ASALs through sustainable production and trade in bio-energy and other forest products aims to increase household incomes derived from forest resources while motivating communities to conserve forest resources.

Under the water sector, we endeavor to provide the rural poor with access to safe water by financing community water supply schemes. Women and children bear the task of collecting water, sometimes from as far as 10km from their homesteads. With predicted increase in variability of rains due to climate change, especially shorter cycles of drought, women and children will have to walk even longer to access water, thereby consuming valuable time for other productive tasks and putting children at risk of not attending school. Our aim is to reduce these distances and reduce risk of use of contaminated water. By so doing, we aspire to contribute to reducing the vulnerability of the rural poor from the vagaries of climate variability. Climate variability poses threat to water resources. We are supporting communities to develop and implement sub-catchment plans to protect these water resources.

In addition to the bilateral programs, Finland supports regional programmes, such as CHIESA, which are directly aiming to reduce the climate change affects.

### 3.1 Challenges

Efforts towards climate sustainability are not without challenges. Taking climate change at face value risks to camouflage the socio-political factors underlying vulnerability of local communities to natural hazards. For instance, although many parts of Kenya have a history of droughts and floods, often, the impacts of these hazards are viewed as a surprise. The recent case of famine in Turkana comes to mind. The reactionary responses, through food aid, are an indicator of the country’s low level of preparedness to anticipate and prepare for these impacts. As a popular columnist in the local media tweeted “you don’t flag off relief food in front of the cameras; you send it quickly, quietly and shamefacedly”, the ideal of a situation in which future episodes of widespread starvation never occur is yet to be reached. There is therefore need to balance attention to both social and bio-physical factors of vulnerability to climate change.

### 3.2 Opportunities

The increasing prominence of climate change and vulnerability discourse provides some opportunities:

i. The Kenya Government, like other regional governments, has been responsive in crafting harmonized means of addressing climate change. The 2010 National Climate Change Strategy was a milestone.

ii. The international community, including Finland, is keen to support national governments to address climate sustainability. As earlier indicated, Finland’s country programme in Kenya is set to improve capacity of different stakeholders to prevent or reduce impacts of climate change.

iii. Many development partners are supporting climate responsive initiatives in Kenya

iv. There is increasing awareness that vulnerability to impacts of climate change goes beyond exposure to natural hazards, to social-political life worlds of people. The need to improve
communities’ incomes, access to markets, infrastructure - roads, telecommunication, water supply - are now viewed as part and parcel of climate-resilient livelihoods.

v. Kenya remains a continental leader in ICT innovations. Other developing countries are following suite. ICT innovations have opportunity to contribute to climate sustainability matters. Examples from Kenya already indicate positive progress with farmers taking on mobile-phone-based insurances against drought and diseases risk as well as receiving and exchanging weather and pasture information.

4. Results expected from CHIESA

CHIESA’s endeavor to strengthen capacities of its partners and stakeholder organizations to better monitor and adapt to climate change aligns well with Finland’s development policy on climate sustainability. CHIESA recognizes the role of knowledge in informing adaptation strategies. The assessment of impacts of climate change on ecosystem services and food security provides knowledge that serves an ex-ante to planning adaptation strategies. But production of knowledge on its own is not enough. It has to be supported by mechanisms for ensuring that it is relevant to the target vulnerable community.

On Wednesday 26th March, 2014, CHIESA Project team will have opportunity to discuss results-based management with the Embassy staff. This will be a great chance for CHIESA to reflect on its project intervention logic to ensure that its activities will lead to realization of tangible results.

With these remarks, it is my pleasure to welcome you and declare CHIESA’s 3rd Annual Project Meeting opened.
Distinguished Guests, Ladies and Gentlemen, I am greatly honoured to be here during the 3rd annual meeting for the Climate Change Impacts on Ecosystem Services and Food Security in Eastern Africa (CHIESA) Project. This meeting is an important event in the calendar of the project as it provides a regional platform for scientific presentations and stakeholder exhibitions and displays. The meeting also provides an opportunity for those invited to interact, share ideas and establish linkages.

This meeting is taking place because climate change poses serious risks for humanity, especially in the developing world. Climate change can no longer be treated as just an environmental challenge. It is a holistic sustainable development challenge. In Kenya, climate change has impacted natural systems, physical and social infrastructure and key economic sectors.

Kenya’s natural resources, particularly its rich flora and fauna, are among the country’s most valuable natural assets. Unfortunately, climate change now threatens to exacerbate depletion of this rich biodiversity that resides in the country’s forest rangelands, wildlife and water resources, as well as coastal and marine ecosystems.

Kenya’s infrastructure, including roads, bridges, railways, ports, buildings and dams is built to acceptable risk limits based on the expected return periods of natural hazards, including severe winds, heavy rainfall and storm surges. However, increasing frequency of severe weather events has breached these thresholds and caused severe damage to the infrastructure.

Climate Change has also impacted Kenya’s key economic sectors, especially, agriculture, tourism, fisheries and forestry. Climate change has led to declining agricultural production due to, among others, variation in rainfall commencement dates, amounts, distribution and cessation; and reduced soil productivity through erosion. It has also caused loss of livelihood arising from loss of livestock, particularly in arid and semi arid land (ASAL) areas due to depletion of natural vegetation and pasture.

With many of the resources needed for sustainable food security in Kenya already stretched, the food security challenges are huge. Climate change will make it even harder to overcome them, as it reduces the productivity of the majority of existing food systems and harms the livelihoods of those already vulnerable to food insecurity.

The overarching climate change-related challenges for all sectors in Kenya are: financing adaptation activities; responding to extreme weather conditions and related disasters; high poverty levels; high vulnerability of the population; pressure on natural resources; and man-made and natural disasters. The overarching challenge in agriculture is to sustainably increase
the national food supply to accommodate a rapidly growing population while preserving a safe operating space for humanity by avoiding dangerous environmental change.

The Government of Kenya is taking Climate Change and its impact on development seriously. The Government has committed approximately Kenya shillings 37 billion (USD 438 million equivalent), while development partners have committed to Kenya shillings 194 billion (USD 2.29 billion) during the period 2005 to 2015, to programmes that have significant or principal climate change component.

The Government and stakeholders are implementing many interventions that have direct and/or indirect relevance to climate change adaptation and mitigation. The interventions cover a wide range of sectors including agriculture, water, energy and infrastructure.

In agriculture, the interventions include promotion of irrigated agriculture, promotion of conservation agriculture and farm forestry, value addition to agricultural products, development of weather-indexed crop insurance schemes, support for community-based adaptation including provision of climate information to farmers, and enhanced financial and technical support to drought-tolerant crops.

Climate Change will, however, continue to pose multiple stresses to animals and plants in many agricultural systems in the coming decades and yet there is a great deal that is unknown about how these stresses may combine. To this end, there is need to refocus and scale up research in agriculture in areas that respond to climate change. This is critical for Kenya, and other countries in the region, whose economy is based on agriculture.

Though research to increase yields is essential to meet broader food security goals, a continuing and accelerating refocusing of research to address a more complex set of objectives is required to meet the challenges of making food production sustainable and responding to climate change. Assessment of neglected crops, fruit and vegetable productivity, effects of stress combinations (including impacts of climate change on pests and diseases of animals and crops), biodiversity and agrosystem efficiency, and the efficient provision of ecosystem services deserve more attention.

The CHIESA project has undertaken many activities geared toward generating information and knowledge on the impacts of climate change on sensitive and unique ecosystems and on their services, especially with regard to agriculture and food security. I urge the project implementers to continue meaningful engagement and involvement with farmers, extension agents, government institutions and stakeholder organisations and to develop and disseminate relevant, applicable and affordable climate change adaptation tools at the farm level.

The Government of Kenya will continue its commitment to promote synergy between agricultural extension and agricultural research, and to enhance partnership between public and other research organisations, including the International Centre of Insect Physiology and Ecology, in tackling the challenges occasioned by climate change.

I wish you well with your deliberations during this meeting and in implementation of pending activities under the CHIESA project. I look forward to successful completion of the project and effective dissemination of the results. I thank you.
CONFERENCE PROGRAMME
<table>
<thead>
<tr>
<th>Time</th>
<th>Event</th>
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<tbody>
<tr>
<td>08:00</td>
<td>Registration at the Thomas Odhiambo Conference Center</td>
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<td><em>icipe Duduville Campus</em></td>
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<tr>
<td>08:45</td>
<td>Welcome and agenda of the meeting</td>
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<tr>
<td></td>
<td>Dr. Segenet Kelemu - Director General, <em>icipe</em></td>
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<tr>
<td>09:00</td>
<td>KEYNOTE: Climate sustainability as a cross-cutting objective in Finnish Development Policy Programme: challenges and opportunities</td>
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<td></td>
<td>Sofie Emmesberger - Ambassador, Embassy of Finland</td>
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<tr>
<td>09:15</td>
<td>KEYNOTE: Climate Change and Food Security in Kenya from the Government of Kenya Perspective</td>
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<td>Dr. Michael Obora - Assistant Director of Agriculture, State Department of Agriculture</td>
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<tr>
<td>09:30</td>
<td>KEYNOTE: Tanzania National Climate Change Strategy 2012</td>
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<td>Eng. Mbogo Futakamba - Deputy Permanent Secretary, Ministry of Water, Tanzania</td>
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<tr>
<td>09:45</td>
<td>Climate Change Adaptation in the Yayu Biosphere Reserve in Ethiopia</td>
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<td>Dr. Tadesse Gole - Environment and Coffee Forest Forum of Ethiopia</td>
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<tr>
<td>10:00</td>
<td>Ecosystem-based Adaptation for Food Security in East Africa</td>
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<td>Dr. Richard Munang - United Nations Environmental Programme</td>
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<td>10:15</td>
<td>Adaptation Actions and Communities</td>
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<td>Ms. Ruth Mitei - CARE International, Kenya</td>
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<td>10:30</td>
<td>Health and Climate Change</td>
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<td>Dr. Andrew Githeko - Kenya Medical Research Institute</td>
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<td>10:45–11:15</td>
<td>COFFEE BREAK</td>
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### Project Partner’s Panel: Key findings of the CHIESA Project

#### Panelist’s statements:

<table>
<thead>
<tr>
<th>Time</th>
<th>Topic</th>
<th>Speaker/Institution</th>
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<tbody>
<tr>
<td>11:15</td>
<td>Integrated Water Resources Management</td>
<td>Prof. Shadrack Mwakalila - University of Dar es Salaam, Tanzania</td>
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<tr>
<td>11:30</td>
<td>Land cover/land use change</td>
<td>Prof. Petri Pellikka - University of Helsinki, Finland</td>
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<tr>
<td>11:45</td>
<td>Integrated Pest Management</td>
<td>Dr. Subramanian Sevgan - icipe</td>
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<tr>
<td>12:00</td>
<td>Economic Valuation of Ecosystem Services and Goods</td>
<td>Dr. Reuben Kadigi - Sokoine University of Agriculture, Tanzania</td>
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<tr>
<td>12:15</td>
<td>Biodiversity and Habitats</td>
<td>Dr. Robert Marchant - University of York, UK</td>
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<tr>
<td>12:30</td>
<td>Panel discussion: Statements are discussed by the Embassy of Finland, UNEP, ECFF, CARE International, KEMRI and Ministry of Agriculture and Ministry of Water</td>
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####scholars fair 1:

**Scholars Fair 1:**

Doctoral degree training scholars - TRO Conference Center, Main Hall

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<thead>
<tr>
<th>Time</th>
<th>Activity</th>
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<tbody>
<tr>
<td>14:00</td>
<td>CHIESA PhD scholars present their key findings and outputs</td>
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<tr>
<td>15:30</td>
<td>Discussion on postgraduate scholars’ presentations</td>
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<tr>
<td>16:00</td>
<td>Welcome cocktail at the Duduville International Guest Center, icipe</td>
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**END OF OFFICIAL PROGRAM FOR DAY 1**

<table>
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<tr>
<th>Time</th>
<th>Activity</th>
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<tr>
<td>17:30</td>
<td>CHIESA WP Level Meeting WP Scientists and scholars</td>
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**END OF OFFICIAL PROGRAM FOR DAY 1**
<table>
<thead>
<tr>
<th>Time</th>
<th>Session</th>
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| 08:00 | Registration at the Thomas Odhiambo Conference Center  
     *icipe Duduville Campus*                                     |
| 08:30 | Climate Change Adaptation in the Academic Programmes of the Jimma University  
     *Dr. Fikre Lemessa - President of the Jimma University, Ethiopia* |
| 08:45 | KMD Forecasting Services and National Climate Change Adaptation in Kenya  
     *Peter Ambenje - Deputy Director, Kenya Meteorological Department* |
| 09:00 | Climate-related research activities at the National Museums of Kenya (NMK)  
     *Dr. Geoffrey Mwachala - Director of Research and Collections, NMK*  |
| 09:15 | The role of academia in national climate adaptation in Kenya  
     *Prof. Chris Shisanya - Dean, School of Humanities and Social Sciences, Kenyatta University* |
| 09:30 | Key findings of the 5th Assessment Report of the IPCC  
     *Dr. Christopher Oludhe - ICPAC/ University of Nairobi* |
|       | **Project Stakeholder’s Panel:**  
     **Panelist’s statements:**                                                                                 |
| 09:45 | Impacts of climate change on water resources in Africa  
     *Dr. Alfred Opere - Chairman, Department of Meteorology, University of Nairobi* |
| 10:00 | The role of KFS in climate change mitigation and adaptation in Kenya  
     *Mr. Alfred Gichu - Head of Climate Change Response, Kenya Forest Service* |
| 10:15 | Climate change impacts on soil and its implications on food security in Kenya: Possible solutions and interventions  
     *Dr. Jane Wamuongo - Assistant Director, Kenya Agricultural Research Institute* |
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<tr>
<th>Time</th>
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<tbody>
<tr>
<td>10:30</td>
<td>Climate change adaptation in the Tsavo ecosystem</td>
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<td>Mr. Dawson Mwanyumba - Taita Taveta Wildlife Forum</td>
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<tr>
<td>10:45</td>
<td>Climate variation and change from the farmers’ point of view in the Taita Hills, Kenya</td>
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<td>Mrs. Violet Mbonje &amp; Mrs. Alice Mwanyota - Farmers’ representatives from the Taita Hills, Kenya</td>
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<tr>
<td>11:00</td>
<td>Panel discussion: statements are discussed by the Jimma University, KMD, NMK, Kenyatta University and ICPAC/University of Nairobi.</td>
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<tr>
<td>11:30–12:00</td>
<td>COFFEE BREAK</td>
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<tr>
<td>12:00</td>
<td>Scholars Fair 2: Master’s degree training scholars - TRO Conference Center, Main Hall</td>
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<tr>
<td>12:00</td>
<td>CHIESA M.Sc. scholars present their key findings and outputs</td>
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<td>13:00</td>
<td>Discussion on graduate scholars’ presentations</td>
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<td>13:30</td>
<td>Closing session – discussion and amendments</td>
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<td>14:00</td>
<td>LUNCH</td>
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<td>15:00</td>
<td>END OF OFFICIAL PROGRAM OF THE MEETING</td>
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<tr>
<td>15:05</td>
<td>CHIESA Steering Committee Meeting/ Meeting for the scholars to share their findings</td>
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<td>19:00</td>
<td>CHIESA Annual Meeting Closing Dinner at the Safari Park Hotel</td>
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SCHOLAR ABSTRACTS

Ph.D. Scholars .......... Pages 17 - 32
M.Sc. Scholars .......... Pages 33 - 42
Effects of climate variability and land cover changes on hydrological processes in Taita Hills, Kenya

Rose Akombo
Department of Geography, Kenyatta University (KU), Nairobi, Kenya

Abstract
Rainfall fluctuation and changing patterns of the landscape may significantly affect water resource distribution in a catchment, intensifying the risks of water scarcity and food insecurity. To address these anticipated threats, water resource managers need to control the effects of the above factors on the catchment’s hydrology. This study aimed to establish historical and future trends of selected hydro-climatic variables and land use / cover change (LUCC) in Wundanyi catchment from 1970 to 2003, then predict their specific and combined effects on surface runoff and streamflow by the year 2030. The analysis was based on statistical trend analysis and dynamic landscape modelling using both historical and primary hydro-climatic data from Wundanyi and Voi weather stations, and Landsat TM and ETM+ imagery of Taita Hills for 1990, 2000 and 2010. These results will be validated by the Soil and Water Assessment Tool (SWAT).

Results show highly variable mean seasonal and annual values of temperature, rainfall and discharge in both Wundanyi and Voi weather stations. Increasing mean temperatures and rainfall were observed during the long dry season (JJAS), while decreasing seasonal discharges were observed during both JJAS and short rainy season (OND). These anomalies were pronounced in 1980-1981, 1986-1987 and 1992-1993, and were probably attributed to both global and local environmental changes affecting Taita Hills in general and Wundanyi catchment in particular. Compared to 1990, major land use/cover changes in 2010 were featured by expansion of built up area (250%), planted forest (23.7%), broadleaved forest (17.4%) and thicket (15.9%) with a decrease in woodland (-30.3%), cropland (-21.6%) and shrubland (-0.8%). Dynamic spatial trends by the year 2030 will be evidenced by increased thicket by 0.41% per annum (R²= 81.6%), and decreased planted forests (-0.13%; R²= 91.3%), woodland (-0.10%; R² = 77.6%), shrubland (-0.11%; R² = 85.2%), broadleaved forests (-0.03%; R² = 56.6%) and cropland (-0.09%; R² of 84.4) will shape the catchment landscape and influence its hydrology, unless the existing forest and agricultural policy interventions are enforced.

The predicted effects of rainfall fluctuation were supported by declining surface runoff of 1.3% during JJAS, and an increase of 0.8% during the OND, with similar effects on river discharges. The above changes in runoff for 1970-2003 were correlated at 60-99% with increasing cropland and shrubland, while the effect for major forest types was below 30%. However, river discharge changes of 20-30% were attributed to planted forests, while only 0.5% was attributed to broadleaved forests. By the year 2030, 3.3 m³/s discharges will be generated from broadleaved forests (against 2.6 m³/s from planted forests). The combined effects of climate variability and LUCC on both surface runoff and river discharges were estimated to 200 mm (JJAS) and 370 mm (OND), and 2.37 m³/s (JJAS) and 1.93 m³/s (OND), respectively. Consequently, natural forest covers have significant control effects on surface runoff and can boost river discharges amid diverse agricultural cropping practices. Hence, crop diversification, agroforestry, and soil and water conservation structures are recommended to maintain effective control of LUCC on hydrological processes going on in Wundanyi catchment.

Key words: water resource distribution, hydro-climatic variables, land use/cover change (LUCC), Wundanyi catchment, Kenya
Crop identification using hyper spectral data: a case study of Taita Hills, Kenya

Mark Boitt
Department of Geomatic Engineering, Jomo Kenyatta University of Agriculture and Technology, Nairobi, Kenya

Abstract

Climate change is one of the most important global environmental issues of our generation and is a subject of many research studies. It is attributed directly or indirectly to human activity and many of its impacts materialise through changes in extreme events such as droughts, floods and storms. Such extremes result in severe human suffering and hamper economic development and poverty reduction. There is need for proper assessment of climate change using scientific skills to reduce the risks and problems arising. The main objective of this study is to identify various crops within Taita Hills and evaluate the effects of climate variation on land use using hyper spectral and satellite imagery. It also identifies possible potential areas that crops can do well and produce a higher yield.

Recent advances in hyperspectral remote sensing techniques and technologies allow us to more accurately identify a larger range of crop species from airborne measurements. This research study employs hyperspectral AISA Eagle VNIR imagery acquired with about 9 nm spectral and 0.6 m spatial resolutions over a spectral range of 400 nm to 1000 nm. The area of study is the Taita Hills in Kenya. Various crops are grown in this region for food and livelihoods. The most important crop species addressed here are maize, bananas, avocados, sugarcane and mango. Spectral signatures of crops are known to vary both within and between the species. The spectral reflectance of vegetation is affected by, e.g. leaf optical properties, leaf angle and spatial distribution.

Emphasis has to be given to the determination of spectral variation of crops to accurately identify species from each other. Contribution of scene components such as soil reflectance and shadows, have to be accounted for as well. One of the main objectives of this study was to learn what crop species can be distinguished from the cultivated population of local crop species, and what feature space discriminates most effectively the spectral signatures of different species. Spectral Angle Mapper (SAM) together with some dissimilarity concepts has been applied in this work. The spectral signatures for crops were collected using accurate field plot maps. Accuracy assessment was done using independent polygons (not used for classification) and achieved an overall accuracy of 77% with a kappa value of 0.67.

Climate variations can hamper the spatial location for growing individual crops. Ecological zones could vary depending on the changes in climate scenarios hence shifting the spatial locations of crops. Land suitability assessment needs to be done and farmers need to be aware from time to time on the best crop practice methods for a better and satisfying yield.

Key words: GIS, GPS, geospatial, WorldClim, IPCC, IDW, DEM
The role of semi-managed coffee forest in carbon storage in Jimma highlands, southwest Ethiopia

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Abstract

The traditional coffee management system has contributed to the persistence of Afromontane forest patches in Jimma highlands. Semi-managed coffee forest (SMCF) is one of four major coffee management systems in Ethiopia, whereby mixed indigenous species of trees are protected for the shade they provide to coffee shrubs beneath them. In the SMCF system, the species composition and vertical structure of natural forests have been modified to provide optimal conditions for coffee growers. In addition to its economic importance, SMCF can be part of climate change mitigation through carbon sequestration and storage. However, the role of coffee shade trees in carbon storage and climate change mitigation has rarely been assessed.

One hectare plots were established along the CHIESA transect in the Jimma highlands of southwest Ethiopia. The transect is 23 km in length and spans 46 km² and 6 land use types, across which the plots were stratified. The diameters at breast height (DBH) and heights of all woody species with DBH ≥ 10 cm were measured within the plots. The plants were identified to species level and voucher-specimens deposited at the National Herbarium, Addis Ababa University. Carbon was calculated using published allometric equations.

In terms of carbon storage, SMCF is the second most (78.87±14.94 ton/ha) important land cover type along the CHIESA transects. Plantation forests (PF) have the most carbon (166.36±6.55/ha), but have much lower value in terms of co-benefits, such as biodiversity, non-timber forest products, pollination services and hydrological function. Pasture (PR) was the least important in terms of carbon (2.24±1.15 ton/ha). Degraded natural forest (NFD) stored less carbon (55.90±25.44 ton/ha) compared to SMCFs.

Significant differences were observed between SMCF and cropland (t = 4.88, p = 0.01, 95% CI (32.48, 114.98), SMCF and PR (t = 5.10, p = 0.01, 95% CI (35.17, 117.95) in carbon storage. There was no statistically significant difference between PF and SMCF (t = -1.50, p = 0.22), NFD and SMCF (t = -0.49, p = 0.68), and woodland and SMCF (t = 3.18, p = 0.03, 95% CI (7.76, 114.83) in carbon storage.

The loss of yield and reduction in coffee price observed over recent years may push farmers to convert their coffee plots to other forms of land use. Here we have shown that if one hectare of SMCF along the Jimma transect were to be cleared for annual crops or pasture, then ~73-77 tons of carbon would be emitted.

Key words: coffee, semi-managed coffee forest (SMCF), carbon storage, climate change, Jimma highlands, Ethiopia
Impact of climate change on coffee diseases in Southwestern Ethiopia

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Abstract

Coffee (Coffea arabica) is one of the most economically important crops in Ethiopia. However, coffee yield and quality are crucially affected by many biotic and abiotic factors. Among them, diseases are the major constraints that are under the control of climatic variables. Management of agroecosystems determines biotic factors such as the diversity and density of trees, which in turn locally influence abiotic factors such as temperature and relative humidity. Nevertheless, little is quantitatively known about their influence and the magnitude of generated changes.

To assess the impacts of temperature and relative humidity within different coffee production systems on coffee berry disease and coffee leaf rust, a study was carried out in the Ageyo-Setema area of southwestern Ethiopia in 2012/2013. Thirty (30) coffee plots of 20 by 20 m from different coffee production systems were selected for assessment of the diseases along the transect. In each plot, 10 coffee trees were randomly selected and from each tree two branches, one from higher canopy and the other from lower canopy, were selected for assessment of the diseases in time.

To further model the disease development as a function of climatic variables, temperature and relative humidity were continuously recorded at each plot during the study period. The results indicated that the prevalence of coffee berry disease increased with elevation resulting in an average infection ranging from 30 to 60%. On the other hand, infection of coffee leaf rust decreased with elevation from 9 to nearly 0 attacks per leaf (corresponding to 15% to almost 0% leaf infected per plot).

Significant effects of climate variables such as the average temperature during the cropping season and the cumulated wetness for each plot were observed on the disease expression. The finding further showed a significant influence of the type of coffee production system on coffee berry disease and leaf rust development.

Coffee production systems characterised by high tree density, were less affected by the coffee berry disease as compared to the coffee systems with less tree density types and vice versa for coffee leaf rust disease. Hence, coffee agrosystem will locally influence microclimate (relative humidity and temperature), and then coffee berry disease and leaf rust development with antagonistic effect. Forest coffee was affected less by coffee berry disease although the temperature was reduced and dew point was increased, which would produce more disease. So, its impact might be indirect like in reducing spore dispersal or related with other variables that normally need further investigation. Finally, minor changes in climate variables as they occur across the Jimma elevation gradient, and are likely to happen in the current climate change context, may strongly impact both coffee cultivation in Ethiopia and its production patterns.

Key words: coffee, Coffea arabica, coffee berry disease, coffee leaf rust, climate change, Ethiopia
Identifying potential areas of understory coffee in Ethiopia’s highlands using predictive modelling

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Abstract

Identification and mapping of understory coffee plants in the Eastern Afromontane Biodiversity Hotspot, specifically the Ethiopian highlands (where coffee production constitutes roughly 41% of the economy), is quite challenging due to understory plantation, defined as the presence of scattered exotic trees and the characteristics of the cultivation. This research aimed to identify and map potential understory coffee areas of Ethiopia’s south-western highlands using predictive modelling. Remote sensing variables such as spectral vegetation indices and shadow fraction, and climatic variables were used.

Results showed that understory coffee plants occupy 37% of the total indigenous forest in the study area considering the probability of greater than 0.50. The probability map of understory coffee forest was validated based on the known understory coffee forest areas. The probability of presence of understory coffee of from 0.75 to 1 was above 55% and 0.50 to 1 was above 72%.

Therefore, this research shows a robust model for locating understory coffee plants, and the extent that remote sensing and climatic variables can be used to manage and conserve these plants, as they play a role in the natural ecosystem (such as in species diversity and habitat, soil conservation, water, carbon storage and climate change).

Key words: understory plantation, coffee, climate change, Ethiopian highlands, indigenous forest
Mapping land use / land cover in Mt Kilimanjaro, Tanzania

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Abstract
Land cover in Kilimanjaro is heavily modified by humans. Large areas of savanna woodlands and grasslands surrounding the mountain have been converted for rain fed or irrigated agricultural use, particularly on the southern side. This dry and hot savanna zone, located between 700 and 1000 metres above sea level (m.a.s.l.), changes into cooler and wetter submontane zone between 1000 and 1800 m.a.s.l. In the submontane zone, most of the natural forest has been converted into a complex small-holder agroforestry system where food and cash crops are shaded by trees in multiple layers. The submontane belt is followed by four distinct forest zones, including a community forest buffer zone, forest reserve and finally the Kilimanjaro Natural Park.

Agriculture and logging are the biggest drivers for land use / land cover (LU/LC) change in the region. The indigenous montane forests inside the natural park are relatively stable, apart from smaller-scale disturbance by forest fires and illegal logging. The agroforestry zone has evolved over several centuries and its expansion has already stabilized simply because it has no area to grow, up or down hill. Therefore, most of the recent LU/LC changes have taken place in the savanna zone, where natural vegetation has been cleared for agriculture and grazing. The potential for agricultural productivity in the lowlands is however lower than in the highlands due to higher temperatures, generally poorer soils, erratic rainfall and dependency on irrigation.

As a first step to understanding the LU/LC dynamics in the region, a baseline LU/LC map has to be generated. This study presents preliminary results of baseline LU/LC mapping. Pan-sharpened Formosat-2 images from January 2012 were used in semi-automatic image classification. The images were first segmented into meaningful image objects, which were then classified into appropriate LU/LC classes using supervised Nearest Neighbor and Rule-Based classifiers. A very detailed LU/LC map with final pixel size of 2x2 meters and a Minimum Mapping Unit of 0.05 ha was generated for the CHIESA research transect, covering a total area of 120 km².

The next steps in the study include multi-temporal LU/LC mapping (1991-2012) in larger scale (with 20x20 meters pixel size) of a study area covering the savanna zone south of Mt. Kilimanjaro. To describe historical LU/LC, similar maps each roughly 10 years apart should be generated. By comparing the multi-temporal LU/LC maps, it is possible to obtain spatial and quantitative information on LU/LC changes that have taken place in the study area. The primary datasets used are SPOT-2 (HRV-2, February 1991), SPOT-4 (HRVIR-2, January 2000) and Formosat-2 (RSI1, January 2012) satellite images. Each image is classified separately using semi-automatic classification methods. The LU/LC classes are defined using LCCS nomenclature created by FAO and UNEP. For calibration and validation of the results, field data collected from study plots will be utilized. Finally, the multi-temporal LU/LC maps are compared using post-classification change detection method, which will reveal the spatial patterns of LU/LC changes during the past 20 years.

Impacts of LU/LC change in the ecosystem and its services will be the final step in the study.
Soil condition and tree stocking on the slopes of Mt. Kilimanjaro, Tanzania: field assessments and local perceptions of climate change impacts

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Abstract
A change in climate around Mt. Kilimanjaro has left local residents vulnerable to climatic shocks, hence the calls for improvement of their adaptive capacity. Generating suitable information is needed to feed the decision support mechanisms that can address these climate change threats. This study has multiple aims, the first to assess the perception of local people on the impact climate change has had on soil conditions and above-ground tree biomass; second, to investigate variation of soil conditions along an altitudinal gradient, and finally to determine variation of above-ground tree biomass along the altitudinal gradient. A total of 50 plots (sized 100 x 100m or 1 ha) were used to record tree data along an altitudinal gradient extending from 680 to 1696 masl over 25 km. Composite soil samples (110) were collected within the vegetation plots from top and sub-soils using the Y-shaped sampling protocol adapted from the continental-wide AfSIS. Household questionnaires (252) were administered in four villages, i.e. two in the highlands and two in the lowlands. Tree stocking parameters were summarised and expressed into per hectare values, i.e. number of stems per hectare (N) and basal area per hectare (G). Soil samples were characterised by the Multi-Purpose Analyzer using near-infrared reflectance spectroscopy and wet chemistry. Data from questionnaire surveys were summarised and descriptive statistics conducted and the remaining information subjected to participatory analysis with local residents.

Preliminary results indicated a decrease of stocking parameters as descending to the lowlands with a clear mark at around 900 m. Tree density was below 20 stems/ha in the lowland and rose to 100 stems/ha in the highlands. The same observation is true for basal, which is relatively lower in the lowland (less than 2.0 m²/ha) compared to highlands (range of 2.1 m²/ha - 7.5 m²/ha). These notable differences can be explained by differences in precipitation and topography between the two areas. Soil characteristics indicated four clear patterns: (i) soil pH, Mg and Ca increase downslope; (ii) K, Na and electrical conductivity is high in the lowland but maintains more constant values above 800 masl; (iii) Al and CEC increased with altitude; and (iv) P and S expressed a U-shaped curve of high values in the lowland and highlands but lowest in the midland. These soil parameters indicate their availability and limiting factors as dictated by topography, temperature, precipitation and land use.
Local perceptions regarding impacts of climate change on soil conditions and woody resources are consistent with the biophysical observations. Of the respondents, 91.6% (n=239) indicated climate change has negative impact on soil conditions leading to soil infertility and poor crop yields, and 78.6% (n = 136) indicated as well decline of tree cover and poor tree recruitment. To cope with these changes, local people have taken measures that include growing crops that are drought-tolerant (90.9%, n = 252), crops with short germination period (99.2%, n = 252) and planting of more trees (77.3%, n = 97). These preliminary results conclude that observations made from biophysical assessments indicated clear link among topography, temperature and precipitation regimes in provision of ecosystem services. Locals, despite being aware of and implementing mechanisms to adapt to these climate change impacts, are facing more difficulties in terms of availability of woody resources and soil health, i.e. soil erosion, flooding and high alkalinity, particularly in the lowlands.

Keywords: Climate variability, trees on farm, soil characterisation, home gardens
Farmers’ perception about changes in climatic variables and adaptation strategies in East Africa: The case of Kilimanjaro in Tanzania, and Taita Hills and Machakos Hills in Kenya

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Abstract

This paper appraises the perception and understanding of subsistence farmers regarding the change of climatic variables and adaptation.

A study was carried out in Kilimanjaro region of Tanzania, and Taita Hills and Machakos Hills in Kenya. A semi-structured questionnaire was used to interview 510 farming households. Findings indicate that farmers perceived changes in rainfall and temperature in the study areas as factors that negatively affect the production and management of crops. Moreover, the analysis revealed that farmers’ livelihoods in the study areas are at risk not only due to climatic but also non-climatic factors such as insect pests, soil fertility and land size. Results further show that the major constraints to climate change adaptation by farmers in the studied regions are lack of information, irregularities of extension services, poor government attention to climate problems, inability to access available information, lack of access to improved crop varieties, no subsidies on planting materials, limited knowledge on adaptation measures and absence of government policy on climate change.

The study concludes that government policies on adaptation need to inform and guide on the risks and opportunities for farmers. In addition, farmers need to adopt sustainable measures by resolving and making conscious decisions based on various climatic (rainfall and temperature) and non-climatic factors (insect pests and soil fertility). Hence, education and awareness on climate change issues need to be prioritised. However, there are important lessons to learn from the self-motivated farmers who do not depend on external support.

Key words: climate change, subsistence farmers, Kilimanjaro region, Taita Hills, Machakos Hills, Tanzania, Kenya
Population dynamics and diversity of *Plutella xylostella* (Lepidoptera: Plutellidae) and its key natural enemies in crucifers farming systems of Mt. Kilimanjaro and Taita hills

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**Abstract**
Interactions between diamondback moth, *Plutella xylostella* (Lepidoptera: Plutellidae), its cruciferous hosts and natural enemies along altitudinal gradients enables understanding of impacts of prevailing weather, and potential climate change on the ecosystem services that naturally influence suppression of pest populations and productivity of crucifers.

In this regard, monthly field surveys were carried out between December 2012 and November 2013 along altitudinal transects of Mt. Kilimanjaro and Taita hills in East Africa to investigate population dynamics of *P. xylostella*, its cultivated hosts (cabbage, kale and Ethiopian mustard), wild cruciferous hosts and key natural enemies.

Each transect was divided into three altitudinal zones (low, medium and high) and surveys were conducted in 11 and 12 farms in Mt. Kilimanjaro and Taita hills, respectively. In each farm, 20 randomly selected plants were sampled. Field sampled larval and pupal stages of *P. xylostella* were taken to the laboratory to assess parasitism. Field observation on parasitism was done in another 10 purposively selected plants. Other key insect pests and farm management practices were also recorded.

Subjected to descriptive statistics for analysis, *Diadegma semiclausum* was the most predominant parasitoid in both transects. In the medium and high altitudes of Mt. Kilimanjaro, it constituted 88.5 and 87.3% of all recovered parasitoids, respectively. In the low altitudes, *Oomyzus sokolowskii* and *Cotesia plutellae* were predominant, constituting 47.5 and 44%, respectively, of all parasitoids. The parasitism rates of *D. semiclausum* in the medium and high altitudes were 30.3 and 28.4%, respectively but only 2.94% in the low altitudes. On the contrary, parasitism rates by *C. plutellae* and *O. sokolowskii* in the low altitudes were 19.11 and 20.58%, respectively compared to only 2.75 and 0.9% in the highlands.

Recovered *C. plutellae* in the high altitudes probably suggests increasing favourable warm weather. In Taita hills, *D. semiclausum* was not only the most significant parasitoid in the medium and high altitudes, but also in the low altitudes where its parasitism rate at 12.72% narrowly outcompeted that of *C. plutellae*, which stood at 12.36%. Numbers of plants attacked by a particular insect pest were used to score pest populations across seasons and altitudes. Cabbage aphid, *Brevicoryne brassicae* and onion thrips, *Thrips tabaci* were predominant in high and low altitudes of Mt. Kilimanjaro, respectively. Generally, insect pest populations were higher during hot seasons (January, February, September and October). Species diversity of insect pests was higher in the medium and high altitudes of both transects. The diversity of wild crucifers was higher in Mt. Kilimanjaro probably due to the common practice of home gardening, with *Erucastrum arabicum* and *Raphanus raphanistrum* being more common. However, wild crucifer numbers declined at low altitudes.

**Keywords:** *Plutella xylostella*, parasitoids, crucifers, seasons, interactions
Soil carbon dioxide emissions in elevated ecosystems: a case study of Taita hills, Kenya

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Abstract

World atmospheric carbon dioxide emissions in the 21st century were estimated at between 20 to 40 GtC (gigatons of carbon), with agricultural production accounting for nearly 10 - 12 % of the total anthropogenic emissions. Current theoretical and empirical models give variable emission estimates for various time-space dimensions, all indicating the sub-Saharan Africa (SSA) region as contributing minimal atmospheric carbon depositions compared to other regions in the world. However, current efforts by sub-Saharan Africa to shift towards agricultural intensification will ardently result to increased atmospheric emissions, whose magnitude remains uncertain given the characteristic variability in SSA ecosystems.

This study presents preliminary findings of soil-borne carbon dioxide gas flux landscapes across gradient ecosystems in Taita hills of coastal Kenya. Flux measurements were conducted from 41 sampling sites comprising of forests, shrub, agroforestry and cereal-maize based land-cover/land-use systems. Actual measurements were done using dynamic chamber gas measurement technique over a period of six months (August, 2012 to June 2013). In each site, 5 chambers were placed at 10 m chamber-to-chamber interval and carbon flux readings recorded on a monthly basis. Additionally, daily rainfall, soil and surface temperatures were obtained during the sampling duration.

Soil CO2 flux increase was positively correlated with rainfall across all land use types assessed during the study period. Maize cropping systems in the lower elevation gradient (< 1100 meters above sea level [masl]) contributed the lowest CO2 flux (0.149 g/m2/hr), which increased threefold (0.6729 g/m2/hr) at gradient rises up to 1500 masl. Similarly, agroforestry systems comprising avocado and mango more than doubled their CO2 flux emissions from 900 masl (0.3216 g/m2/hr) to >1500 masl (0.6636 g/m2/hr). Natural forested systems, predominant in higher (> 1350 masl) altitude zone contributed the highest CO2 flux (0.826 g/m2/hr), which is 3.7 times higher compared to shrub-lands predominant in lower (>1300 masl) zones. Although supplementary soil organic carbon (SOC) and weather data are needed to adequately explain the trends and relationships observed for CO2 emissions, the results present a snap-shot of carbon dynamics in tropical ecosystems.

Further, these findings underscore inherent heterogeneity in soil physico-chemical conditions in elevated sub-Saharan Africa ecosystems and land use trade-offs in mitigating atmospheric carbon dioxide emissions.

Key words: Soil, CO2 flux, gradient ecosystem, emissions, heterogeneity
Identification of tree species using airborne hyperspectral data: A case study of Ngangao Forest in Taita Hills, Kenya

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Abstract

In Kenya, forest mapping has been restricted to either exotic or indigenous level, and only tedious and time consuming methods have been used to identify trees at species level. The development of high spectral resolution sensors has provided new possibilities for mapping forests at species level using remote sensing techniques. Remote sensing techniques offer fast, up-to-date and accurate methods of distinguishing between different tree species (Peerbhay et al., 2013). In this study, the feasibility of Airborne Imaging Spectrometer for Applications (AISA) Eagle VNIR data for spectral discrimination of indigenous and exotic tree species in Ngangao forest (120 ha) was examined. Furthermore, the classification accuracy was tested to establish whether there was improvement by using narrowbands in comparison to simulated broadbands in VIS-NIR range.

The hyperspectral images (129 spectral bands) were acquired using AISA Eagle VNIR sensor (400–876 nm, bandwidth approximately 4.6 nm) in February 2013, at a mean flying height of approximately 2300 metres above sea level (masl). The images were radiometrically and atmospherically corrected using CaliGeo Pro and ATCOR-4 software, respectively. A DEM of 20 m spatial resolution was resampled to 1 m resolution and used to ortho-rectify the images. The images were then geometrically corrected in ENVI 4.8 software using the GLT files generated by the CaliGeo Pro software. High-resolution aerial photographs, taken in January 2012 using Nikon D3X digital camera were used in the field to delineate tree crowns, identifiable both on the images and on the ground. The crowns were then on-screen digitized on the true colour composites of the AISA images.

For the preliminary analysis, a total of 152 samples were digitised representing 10 different tree species (Table 1).

<table>
<thead>
<tr>
<th>Species</th>
<th>Type</th>
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<tbody>
<tr>
<td>Acacia mearnsii</td>
<td>Exotic</td>
<td>11</td>
</tr>
<tr>
<td>Cupressus lusitanica</td>
<td>Exotic</td>
<td>10</td>
</tr>
<tr>
<td>Eucalyptus spp.</td>
<td>Exotic</td>
<td>21</td>
</tr>
<tr>
<td>Pinus patula</td>
<td>Exotic</td>
<td>29</td>
</tr>
<tr>
<td>Albizia gummifera</td>
<td>Indigenous</td>
<td>37</td>
</tr>
<tr>
<td>Ficus thonningii</td>
<td>Indigenous</td>
<td>10</td>
</tr>
<tr>
<td>Macaranga capensis</td>
<td>Indigenous</td>
<td>14</td>
</tr>
<tr>
<td>Newtonia buchananii</td>
<td>Indigenous</td>
<td>7</td>
</tr>
<tr>
<td>Ocotea usambarensis</td>
<td>Indigenous</td>
<td>5</td>
</tr>
<tr>
<td>Syzygium guineense</td>
<td>Indigenous</td>
<td>8</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td><strong>152</strong></td>
</tr>
</tbody>
</table>
The average spectral reflectance of each tree crown was extracted from the AISA image for each of the 129 spectral bands. The average spectral reflectance of each tree species was then calculated. Selected vegetation indices (VIs) were computed from hyperspectral data and formed additional inputs in the discrimination of tree species. Finally, four broadbands were calculated from the AISA spectral bands as the mean of the spectral reflectances for their respective wavelength ranges. The Stepwise Discriminant Analysis (SDA) in PASW Statistics 18 software was used for statistical analysis and classification of individual tree species using three sets of inputs: (1) all narrowbands, (2) a combination of narrowbands and selected vegetation indices (VIs), and (3) simulated blue, green, red and NIR broadbands.

According to the preliminary results, both the narrowbands and VIs provided a cross-validated overall accuracy of 77.0%. The simulated broadbands provided considerably lower overall accuracy of 38.2%, which emphasizes the utility of hyperspectral data in tropical tree species discrimination. High overall accuracy (92.8%) was attained when separating only exotic and indigenous species.

In the three classification options, the classification accuracies of *Acacia mearnsii*, *Cupressus lusitanica*, *Ficus thonningii* and *Syzygium guineense* were relatively low as compared to the other species. This could be attributed to the few numbers of training samples collected for each of these tree species (Matthew et al., 2005) but also to spectral similarity of those species. The indigenous forest in Ngangao is characterised by mixed and dense canopy. Regardless of this, the identification of the selected species was generally successful and this could improve with increase in the number of crown samples. In addition, other classification methods such as Spectral Angle Mapper (SAM) could be tested to check the quality of the results.

Key words: AISA Eagle, hyperspectral, tropical forest, tree species, Taita Hills, Kenya
The role of climate change induced effect on biology and ecology of avocado insect pests along the altitudinal gradient of Taita Hills, Kenya and Mount Kilimanjaro, Tanzania

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Abstract

Climate change is the most significant global environmental challenge, which poses a serious threat to agriculture by impacting on population dynamics of crop pests and their related enemies. These effects can be through the influence that weather may have on insects’ behaviour and physiology. Host plants (including avocado), and parasitoids or predators of the pests can also have the same result.

One of the major problems that horticultural farmers in East Africa face is increase in insect pests of avocado, *Persea americana*. The key pests include thrips, false codling moth and fruit flies, which have detrimental effects on quality of avocado fruits, leading to quarantine restrictions, and therefore economic loss. Ongoing study in farmlands along altitudinal gradients of Taita Hills, Kenya and Mount Kilimanjaro, Tanzania provides an opportunity to identify and analyse problems facing avocado farmers. These mountainous ecosystems of eastern Africa are characterised by steep elevation gradients along habitats, ranging from lowland areas to heathland communities at high altitudes. Therefore, the impact of climate change on pest species richness and abundance of key insect pests of avocado may be more profound in such areas. This is largely because the mountains have relatively intact habitats and steep elevations that allow species to track changing environment over short distances or altitudes. Each altitudinal zone has associated weather patterns or environmental parameters. Furthermore, a sudden change in environmental parameters may enhance insect pest outbreaks in areas with altitudes that have never experienced it.

The broad objective of the study was to assess the effects of climate change on avocado insect pests and further generate species distribution models using present and projected climate change scenarios that can be extrapolated to other avocado farming areas in eastern Africa. The prediction of potential pests’ distribution patterns under climate change scenarios was generated by GIS-based species distribution models. The insect pests’ life table laboratory experimental and environmental data will be used to predict species distribution models of key insect pests. The study established that *Bactrocera invadens*, false codling moth (*Thaumatotibia leucotreta*) and thrips (*Heliothrips haemorrhoidalis*) are the major pests of avocado fruits, flowers and leaves. False codling moth and *Bactrocera invadens* were more abundant in altitudes below 1500m in both transects but Taita Hills recorded the highest. The abundance of false codling moth and *Bactrocera invadens* increased with ascending monthly mean temperature in both regions. December, January and February had highest abundance. *Heliothrips haemorrhoidalis* was more abundant in altitudes above 1200m. The study also established that temperature was the most significant environmental parameter that affects abundance of avocado insect pests.

Key words: avocado, *Bactrocera invadens*, *Thaumatotibia leucotreta*, *Heliothrips haemorrhoidalis*, Taita Hills, Mt Kilimanjaro
Assessing forest carbon altitude relationships across East African mountains: insights from Taita Hills (Kenya) and Kilimanjaro (Tanzania)

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Abstract
Understanding the linkages between carbon storage, biodiversity and livelihoods is of interest as climate and land use changes are increasingly impacting mountain ecosystems and the people who inhabit them. In mountainous areas, elevation and climate play an important role in habitat, species distribution, leaf area index and carbon storage quantity and distribution, although there is need to improve knowledge on the impacts of land use and climate change on habitats and interactions via carbon stores. An understanding of how ecological processes impact on ecosystem goods and services is also important.

The main aim of the study is to derive aboveground biomass/carbon measurements and their relationship with elevation gradients in the Taita Hills (Kenya) and Mount Kilimanjaro (Tanzania), that are part of the wider Eastern Afromontane Biodiversity Hotspot (EABH). CHIESA’s Taita and Kilimanjaro transects run from low to higher elevations; from Mwatate to Vuria Hill, and Miwaleni springs to Kirua-Vunjo, respectively. These transects are characterised by agricultural crops, forest (indigenous and plantations), woodland and bushland, as well as wetlands along the elevations. Bushland species occur in the lowland areas of the mountains; woodland species are predominant in the midlands, while forest species occur mostly in the highland areas.

A total of 33 1-ha plots were studied; 13 in Kilimanjaro area and 20 in Taita Hills. Species abundance, identification, diameter at breast height and Leaf Area Index were measured within each plot. Preliminary data exploration and analysis of carbon and elevation data was carried out in Excel and R. Allometric methods developed by Chave et al. (2005) were used to calculate aboveground biomass; the dry forest stand model was used at low and mid elevations, while moist forest stand model was used at upper elevations. The Above Ground Carbon (AGC) was calculated for each stem by assuming 50% of biomass is carbon.

Preliminary analysis shows that the Taita Hills has more carbon storage (59.1 t/ha) than Kilimanjaro area (29.7 t/ha) but the latter has more carbon stored in agricultural areas than Taita Hills. The greater species diversity and carbon in the upper Taita Hills elevations is in contrast with agricultural areas. Regression performed on carbon storage and elevation shows strong relationships (r² = 0.654) for Kilimanjaro area and weak relationships in Taita Hills (r²=0.145). In the Taita Hills, Syzygium guineense contributes more carbon (4.9 t/ha) and Pinus pituda (4.1 t/ha) though these occur only in the upper elevation. Albizia gummifera (5.7 t/ha) contribute more carbon in the Kilimanjaro transect followed by Persea americana (2.1 t/ha). Within lower elevations categories in Kilimanjaro area Adansonia digitata (2.0 t/ha) contribute more carbon; while Albizia gummifera contribute more in mid elevation (4.4 t/ha) and upper elevation (1.2 t/ha). In Taita Hills, Terminalia brownii contribute about 0.6 t/ha more than other species at low elevations, Eucalyptus sp. 1.1 t/ha in mid elevation and Syzygium guineense 4.9 t/ha in upper elevations. Thus, different species dominate the carbon storage budgets on Mount Kilimanjaro and the Taita Hills; this is vital information that can be used to inform future management as policies are introduced to maximise carbon storage of mixed agro-forested areas.

Key Words: habitat/biome, species, elevation gradient, carbon storage, land use
Analysis of rainfall distribution in Eastern Africa: a comparison of observed meteorological data and a regional climate model ensemble

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Abstract
Rainfall is fundamental to the biological, social and economic prosperity of eastern Africa. The distribution of rainfall of eastern African countries is highly variable both in space and time. Multiple large-scale drivers that contribute to this variability include annual migration of the Inter-Tropical Convergence Zone (ITCZ), the El Nino Southern Oscillation (ENSO) and the Indian Ocean Dipole (IOD). At local scales, rainfall patterns are further influenced by proximity to the coast, large water bodies such as Lake Victoria, and complex topographical variations associated with mountains and highlands of the Great Rift Valley. Increased rainfall variability attributed to climate change has been observed over eastern Africa in the recent past. General Circulation Models (GCMs) are used to simulate observed and future climate patterns. Currently, GCMs cannot resolve regional climate with complexities like those of eastern Africa. In this study, the ability of high resolution Regional Climate Models (RCMs) to capture rainfall patterns both at regional and sub-regional scales for provision of valuable information for climate change impact assessments is explored.

RCM outputs from the Swedish Meteorological and Hydrological Institute (SMHI-RCA4), obtained through the Coordinated Regional Climate Downscaling Experiment (CORDEX) are used to simulate rainfall patterns over Eastern Africa. The models provide regionally downscaled historical (1951-2005) and future (2006-2100) climate datasets from eight driving GCMs at 0.44° (~50 km) resolution. The RCMs were compared with Era-Interim and satellite-derived data from the Tropical Rainfall Measuring Mission (TRMM) at continental (Africa) and regional (Eastern Africa) levels. At sub-regional scales and within the Climate Change Impacts on Ecosystem Services and Food Security in Eastern Africa (CHIESA) project countries of Kenya, Tanzania and Ethiopia, we further validated RCM output using observed rainfall data from meteorological stations (1989-2005). The skill of the model is assessed using statistical methods such as correlation analysis, Student t-test and root mean square error.

Compared with sub-Saharan Africa as a whole, RCM output for eastern Africa was found to be better at seasonal/annual time-scales. Major seasonal rainfall seasons are not well reproduced by the models when evaluating rainfall over the whole of African continent and models capture only one long rainfall season (October-May) when the evaluation is performed over eastern Africa. At sub-regional levels of eastern Africa, the models simulate the unimodal rainfall patterns of the southern and northern extents better than the bimodal rainfall patterns experienced over equatorial regions (5°S-5°N). Specifically, the models underestimate observed rainfall over the wet areas of the Lake Victoria Basin, the Coast and the central highlands. The models underestimate the observed March-May (MAM) rainfall season, while they overestimate October-December (OND) rainfall over the CHIESA study sites of Taita hills and Kilimanjaro respectively. The overall assessment indicated that regionally downscaled rainfall from MPI, MIROC, ICHEC and CNRM RCMs were the best for eastern Africa region. It was concluded that the RCMs simulate the rainfall of eastern Africa except for areas near the equator, where seasonal rainfall patterns are most complex. Model simulations and future projections ought to be treated with appropriate caution.

Key words: Inter-Tropical Convergence Zone (ITCZ), the El Nino Southern Oscillation (ENSO) and the Indian Ocean Dipole (IOD), rainfall variability, climate change, eastern Africa
Economic valuation of agroecosystem goods and services along the altitudinal gradient of Mount Kilimanjaro in Tanzania

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Abstract

The Eastern Afromontane Biodiversity Hotspot (EABH) has important agroecosystem service values arising from the water towers it provides for the low-lying areas, food production from major crops like maize, banana and cabbages and plantation crops like coffee and avocado, recreation and eco-tourism, habitats and nutrient recycling. Despite their importance, the agroecosystem goods and services in EABH are poorly understood, scarcely monitored, and in many cases undergoing rapid degradation and depletion. They are often valued more for their development potential rather than their provision of goods and services. Most of the benefits that accrue from the use of agroecosystem goods and services, which are not sold in markets, are normally not quantified in economic terms. As a result, they are often overlooked or taken for granted as free (valueless) or gift from God. This in turn has resulted in undervaluation of the economic values of ecosystem goods and services. Consequently, these benefits are largely ignored in the planning and decision-making processes, leading to mismanagement of the ecosystems and hence serious environmental problems.

To better align ecosystem conservation with economic forces, it is important to undertake economic valuation of this natural capital. The overall objective of this study is to assess the economic values of agroecosystem goods and services along the altitudinal gradient of Mount Kilimanjaro in Tanzania. Specifically, the study will identify the agroecosystem goods and services available in the study area, quantify the economic values of the agroecosystem goods and services, and evaluate dynamics in the stock of agroecosystem goods and services by altitude and time. The study will use the Integrated Valuation of Environmental Services and Tradeoffs (InVEST) model, one of the more sophisticated software tools for economic valuation of ecosystem goods and services.

The study design will be cross-sectional for household survey. The study area will be stratified into three altitudinal zones: lower, middle and higher altitudes, and samples will be collected from each of the zones. A structured questionnaire will be used to collect primary data at household level on socio-economic characteristics of the respondents and on the types of the available agroecosystem goods and services and their use. Data will also be collected through focus group discussions (FGDs) to gather general information regarding types and characteristics of the agroecosystem goods and services obtainable in the study area. Secondary data will be collected from various documents such as books, research reports, periodicals, project reports, journals and websites. Qualitative data from FGDs and questionnaires will be analysed by Content Analysis while quantitative data will be analysed using Statistical Package for Social Science (SPSS) computer software. The InVEST modelling suite will be used to quantify the amount and value and to evaluate the dynamics in the stock of agroecosystem goods and services by altitude and time under future scenarios.

Key words: agroecosystem service values, agroecosystem goods and services, Mount Kilimanjaro, Tanzania
Assessment of the potential for integration of ecosystem based approaches and local indigenous knowledge into climate change adaptation in the Taita Hills, Kenya

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Abstract

Knowledge on climate change perception of smallholder farmers is important in the formulation of adaptation strategies. The integration of indigenous knowledge and science through ecosystem based adaptation provides a basis for the formulation of culturally acceptable and sustainable adaptation practices.

The Taita Hills in Kenya hosts endemic flora and fauna which are important for the global and regional biodiversity and livelihoods of the smallholder farmers in the area. However, climate variability has resulted in crop failure and consequently the farmers in the area have suffered losses; these coupled with the reactive climate change adaptation strategies exacerbate the impacts of climate change.

This study aimed to: (i) determine the households’ perception of the impacts of climate change in their ecosystem and how their perception compares with climate impact studies conducted in the area; (ii) determine the socio-economic factors that increase households’ vulnerability to the impacts of climate variability and change, and (iii) determine the climate adaptation strategies that are in use in the Taita Hills and assess their suitability for the agroecological zone for which they are in use. It used a mixed methodology that involved literature review, participatory rural approaches and household surveys.

As a result it emerged that adaptation to climate variability and change in the Taita Hills, takes on both an anticipatory and reactive approach. Of the farmers, 68% have experienced the impacts of climate change and have taken up adaptation strategies. It also emerged that the unpredictability of the long and short rainy seasons and the poor distribution and low amounts of rainfall mainly constitute their perception of climate change. However, with regards to farm water management as an adaptation strategy, only 51% of the households have initiated farm water management measures. Furthermore, socio-economic parameters such as farm size and dependency ratio render the households vulnerable to climate change.

Finally, the Taita people possess sufficient indigenous knowledge for climate change adaptation that can be utilised together with EBA approaches for an integrated approach to climate change adaptation.

Key words: smallholder farmers, climate change, Taita Hills, Kenya
Abstract

Kikuletwa and Ruvu catchment areas have been experiencing river discharge decreases, which have in turn interfered with water provision to the communities against rising demand for water brought on by factors including population increase and land degradation.

The effects of socio-economic activities lead to land use changes which directly or indirectly affects water resources within the catchments. Degradation in the flow characteristics decreased the reliability of water resources. This study investigated the impact of land-use/cover change for 23 years, from 1987 to 2010, on stream flows upstream of NyM reservoir, Kikuletwa and Ruvu catchments.

The purpose of this investigation was to provide evidence for land-use/cover changes occurring in the catchments, and their consequences on stream flows. This was determined by variability analysis of time series (monthly, seasonal and annual), minimum and maximum flows from the river gauging stations in the catchments, land-use/cover change detection and impact analysis using SWAT model. The variability analysis during the studied period 1987-2010 has shown increasing trends in 1987 and earlier; backward and decreasing trends towards 2010 in Kikuletwa rivers while Ruvu river has shown a decreasing trend in 1987 and earlier, and increasing trend onward.

For instance on 1DD1 station the low flows decreased by 0.05 (Q90) and 0.43 (Q95) against the statistical limit of 1.96 during 1994 - 2010. The land-use/cover types were determined using the unsupervised image classification method on Landsat TM and ETM+ data using ERDAS IMAGINE 2011, then ArcGIS 10 was used to detect the changes. Results from LUCC have shown changes in the catchments; the conversion of forest, grassland and bushland to cultivated land and settlement has been observed between 1987 and 2010, with an increase of 7.7% in cultivated land and 0.1% in settlement and built up area. The results also indicated 2% decrease of forest, 8.9% decrease of grassland, 1.5% decrease in woodland and 0.4% decrease in swamps. Grassland has shown highest percentage of change to other land-use/cover types mainly to bushland and cultivated land (12.23 and 11.72% respectively). The land-use map of 2009 was used to setup SWAT model and maps of 1987 and 2010 were used to analyse the impacts of LULCC on stream flows.

Results from SWAT simulations indicated decreasing average river flows from 100.907m³/s in 1987 to 100.441m³/s in 2010, a difference of 0.466m³/s in Kikuletwa, and a decrease from 67.522m³/s in 1987 to 67.415m³/s in 2010, a difference of 0.107m³/s in Ruvu. These differences are not significant but with increasing LULCCs among other factors, the stream flows are continually at threat of diminishing, thus affecting water provisions in the sub-basins. The study recommended improving data management, establishment of good network of both hydrometric and meteorological stations as well as catchments conservation in order to restore the water resources for sustainable development.

Key words: land-use/cover change, Kikuletwa and Ruvu water catchment areas, Tanzania
Traditional weather forecast dissemination practices, challenges and opportunities: The case of Kilimanjaro (Tanzania)

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Abstract

Although climate change-free agricultural production in Africa is impossible, climate change-resilient agricultural production is not. How farmers adapt to climate change and variability impacts will depend greatly on whether they are able to locally predict weather patterns (such as rainfall fluctuations), and their ability to apply the prediction appropriately to make informed decisions on agricultural production.

Observed increase in climate variability in most East African countries has increased the uncertainty in seasonal rainfall predictions. This has posed a greater challenge to scientists in their efforts to improve weather forecasts’ accuracy and reliability. Moreover, rural communities in East Africa scarcely use indigenous knowledge-based weather forecasts in farm-level decision-making to cope with climate variability. Sustainability of this practice is challenged by inadequate identification and documentation, rapid disappearance of prediction indicators and its custodians, and reluctance of younger generations to adopt and use it.

A number of studies have already been done on this discourse. The most understudied area of this science is on the existing communication pathways between predictors (conventional and indigenous predictors) and users.

Based on these challenges, a study is proposed along the Kilimanjaro transect to fill the knowledge gap. Expected outcomes are explanations to two main questions: (i) What indigenous weather forecasting practices exist in the proposed study area and how do farmers use and perceive them?, and (ii) What are the existing communication pathways and how efficient are they? A combination of participatory research approaches (PRAs), community household (HH) surveys, and interviews with various experts and key informants will be used.

The expected findings will help to further understand how indigenous forecasting knowledge (IFK) and seasonal climate forecasts (SCF) can be integrated to enhance uptake and use among users, advise national policy on future weather forecasts, and in capacity building.

Key words: weather, climate change, climate variability, Kilimanjaro, Tanzania
Farmers’ adaptive capacity to climate change: constraints and opportunities in Mount Kilimanjaro, Tanzania

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Abstract

Climate change adaptation is manifested through familiarity with, perception of and adaptive capacity of the climatic events. The overall objective of this study is to assess the farmers’ perception of and their adaptive capacity to climate change, including constraints, opportunities and acceptance of the particular adaptive strategies.

For this objective to be met, these main questions must be answered:

• What are the farmer’s perceptions to climate change, the trends in climate change indicators and crop production for the last 30 years (1983-2012) in Mount Kilimanjaro area?
• What are the climate change adaptation options and strategies utilised by farmers in Mount Kilimanjaro area?
• What is the Households’ Climate Change Vulnerability Index of the population in Mount Kilimanjaro?

Data for analysis will be from both secondary and primary sources. Primary data will be obtained using different Participatory Research Approaches (PRA) including household questionnaires and focus group discussions, as well as key informant interviews and observation of the adaptation strategies practiced by farmers in the field. Secondary data will be obtained from the Tanzania Meteorological Agency, National Bureau of Statistics and Moshi Rural District Agricultural Department.

Quantitative analysis of the data will be done by computation of frequency distributions and some selected measures of central tendency and dispersion. The Lorenz Curve will be charted to represent the dispersal of annual rainfall, annual temperature, number of rain days and average yields of staple food in the district for the past 30 years (1983–2012). Computation of Gini coefficient for distribution of rainfall, annual temperatures, number of rain days and average yields of staple food in the district for the same period will be included. The computation will be based on the direct expression of the Gini Index in terms of the covariance between level of rainfall, annual temperatures, number of rain days and average yields of staple food and their respective cumulative distribution.

The findings from this study will be substantive for policy makers and planners, as they will provide empirical information useful to enrich existing and forthcoming policies on climate change and food security for sustainable development. Since the impact of climate change on agriculture and food supply includes shortage in grain production, resulting in reduced availability of food items, especially to the economically poor people, knowledge of coping strategies adopted by farmers and mitigation of the effects brought by climate change can help in providing an insight into how to deal with the impact effectively and efficiently. Moreover, this study will contribute to available knowledge on the suitability of adaptation options.

Key words: climate change, adaptation options, food security, Mount Kilimanjaro, Tanzania
Investigation of surface water availability dynamics by using coupled SWAT and WEAP models: case of upstream of Pangani River Basin

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Abstract

Surface water as the major source for water related activities in the Upstream of Pangani River Basin (UPRB) has been reported in different studies as decreasing, therefore raising alarm for its sustainability.

This research was therefore designed to study the dynamics of current and future surface water availability to different water use sectors in UPRB under climate change. Multi-tier modeling technique was used for the study by coupling the Soil and Water Assessment Tool (SWAT) and Water Evaluation And Planning (WEAP) models to simulate streamflows under climate change and assess scenarios of future water availability to different socio-economic activities by year 2060. Six common GCMs from WCRP-CMIP3 with SRES emission scenario A2 were selected. These are HadCM3, HadGEM1, ECHAM5, MIROC3.2MED, GFDLCM2.1 and CSIROMK3. They were downscaled by using delta method and LARS-WG to station scale. The SWAT was therefore calibrated with observed data and utilized the LARS-WG outputs to generate streamflows which finally used in WEAP to assess the water availability to different socio-economic activities.

GCMs results show rainfall increase in UPRB between 16-18% in 2050s relative to 1961-1990 periods. Temperature also will increase by average of 2ºC in 2050s relative to this baseline period. A reduction by 5.3% of the annual flows due to climate change impacts is expected by this period. This decrease of streamflows and annual demand increase (72.88% increase by 2060) results to rise of annual unmet demand from 614.29Mm³ in 2011 to 1,783.60Mm³ in 2060 (190.35% increase). The magnitude of the impact will be severe on irrigation which will be 71.12% unmet, followed by HEP (27.47%), livestock 1.41% and domestic (0%).

It can therefore be foreseen that, the plausible climate change and future demand expansion may raise pressure on the demand side due to increased unmet demands. However future studies have to customize the SWAT database more and disaggregate the mixed crops to improve the model performance. Also, the use of more available observed climate data and parameters may provide better calibration results of the models. Furthermore, projections of land cover and soil properties can significantly alter these predictions.

Key words: surface water availability, water use, climate change, Pangani River Basin, Tanzania
Use of conservation agriculture and integrated pest management as tools for reducing farmers’ vulnerability to impacts of climate change and variability in the Taita Hills, Kenya

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Abstract

The effects of climate change on food security and water supply are already visible, especially in the developing world. This is of major concern considering the fact that many small-scale farmers rely on rain-fed agriculture for food production. It also serves as their major source of income. One of the most widely recognised components for response to climate change is adaptation. The extent to which these small-scale producers feel the effects of climate change and variability largely depends on the level of adaptation. However, this is also determined by the degree of vulnerability and the exposure or adaptive capacity of an individual or household.

The present study will evaluate the effectiveness of conservation agriculture and Integrated Pest Management (IPM) as possible tools that can be adopted by farmers to help adapt to climate change and variability among the small-scale farmers in Taita hills. The study will be carried out in the Taita Hills, which is the Climate Change Impacts on Ecosystem Services and Food Security in Eastern Africa (CHIESA) project target area for Kenya. The transect area runs from Mwatate at latitude 3°30’S and longitude 38°22’7’’E to Vuria at latitude 3°25’S and longitude 38°17’5’’E.

Data on farmers’ vulnerability will be collected through administration of household questionnaires and focus group discussions with key informants and household heads, to evaluate socio-economic factors that make them vulnerable. Environmental context data will also be collected on incidences of major crop pests and diseases in the area, methods used for soil conservation, seed selection and farming practices used, in order to identify the existing gaps to adaptation. Experimental plots with common beans as the test crop will then be set-up to serve as learning points for farmers on the appropriate conservation agriculture (CA) and IPM practices, using the mother - baby trial approach.

Data will be collected on biomass yields from the different treatments, which will entail an absolute control, farmer practice plot and minimum tillage with IPM system. This will facilitate comparison of common bean biomass production under the use of different agricultural practices thus providing a pointer to the effectiveness of CA and IPM in reducing farmers’ vulnerability to climate change and variability. Statistical analysis of the collected data will be done using the R-software.

Key words: mother – baby trial design, IPM, conservation agriculture, climate change, climate variability, Taita Hills, Kenya
Impact of climate variability on household water access in Moshi Rural District in Tanzania

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Abstract

Links between climate variability impacts and water are poorly understood in Moshi rural area due to inadequate incorporation of climate-related trends as a tool for better understanding the water access problems in the catchment area.

This study provides a comprehensive analysis of climate variability impacts on water availability and access at seasonal time scale using a linear regression and multinomial model. Historical climate data for a period of 30 years and daily stream flow data for a period of 10 years were statistically processed to reveal trends in rainfall and hydrologic response. Under less variable climate condition, rainfall variability at seasonal timescale was useful in estimating stream flows (a proxy to water availability). During March-April-May rainfall seasons, rainfall explains about 82.6% of the variations in stream flow.

The model achieved a regression estimate accuracy of 68.2%. Findings suggest that as climate becomes more variable hydrologic trends may become less predictable resulting to unreliable water supply, management and access. Analysis also revealed that floods and heavy rains had direct negative impact to water access due to pollution of the water sources. Households in Rural Moshi district spend relatively less time in water collection and as such access to water is within a reasonable distance and time.

While noting the contribution of non-climatic factors, there exist complex but deterministic interactions between climatic factors and hydrology of the catchment that are vital in determining water access. This study demonstrated that climate variability has significant negative impact on seasonal water provision when rainfall variation anomaly is large. The study recommends use of flow estimates at the catchment area in addressing water problems emanating from seasonal water shortages. Future research may include analysis of impacts of climate factors on the interaction between sub-surface flow and stream flow.

Key words: water access, climate variability and change, catchment hydrology, regression estimate, water availability, water resources management
Diversification of agricultural crops as an adaptation strategy to climate change: farmers’ perceptions and approaches in the Taita Hills, Kenya

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Abstract

Most of Kenya’s population is based in the rural areas, where livelihoods are almost entirely dependent on agriculture. Most households practice subsistence farming. However, increased demand for food and other needs has led farmers to practice intensive agriculture, with emphasis on one or two crops.

Climate variability and change are fast becoming a deterrent to agriculture. In the recent past, crop failures, occasioned by increased temperatures and erratic rainfall have become the norm, and this in turn threatens livelihoods and increases vulnerability among many members of the community as they are unable to meet their day-to-day needs. Since most farmers are unable to afford extra inputs to enhance yields, a cheap, cost-effective and efficient way to help them meet their daily needs is necessary.

While it is not a new concept, previous research on crop diversification suggests that it has the potential to increase yields. It is cost-effective, helps reduce pathogen transmission, suppresses pest attacks and cushions against total crop failure in case of failed rains. Crop diversification also improves soil fertility.

The aim of the research, then, is to determine: (i) if diversification of agricultural crops helps farmers to better adapt to climate variability and change, and (ii) if they have embraced the system of diversity in agricultural crops grown on their farms. If so, the study aims to determine how crop yields compare and what other benefits are derived from having diverse agricultural crops. Additionally, farmers’ view of crop diversification as a strategy to cope with weather extremes will be studied.

The research will be conducted in the Taita Hills, Kenya, and will use key informant interviews, household surveys and an ecological survey as the methodologies of choice. The research will document the crops that thrive in the area and the economic impact of these crops on the livelihoods of the farmers. The study will also encourage farmers to grow more of these crops.

Key words: climate variability and change, subsistence farmers, crop diversification, Taita Hills, Kenya
Abstract

Generally, the study aims at assessing maize-coffee-banana agroecosystems’ resilience to climate change in Kilimanjaro Region, Tanzania, with specific focus on identifying farming practices and assessing their susceptibility to the impacts. The study will also examine the socio-economic status of the farmers in Kilimanjaro Region and their capacity to adapt to the impacts of climate change, as well as examine the agroecosystems’ natural resilience and assess their susceptibility to the impacts of climate change.

In this study, three sampling procedures will be undertaken: purposive sampling, simple random sampling and proportionate sampling. Data collection methods will involve tools like household questionnaires, focus group discussions and transect walks. The obtained data will be analysed by SPSS. This software will run frequencies, regression, cross tabulations and the like.

The expected study is anticipated to come up with the community’s social-economic and environmental status, which will likely determine how vulnerable to climate change the agro-ecosystem will likely become. Farming systems/agronomic practices that are employed by the indigenous farmers, and how they are related to the status of adaptive capacity to climate change currently and in the future, will also be disclosed. Further, the expected research will employ the computation of vulnerability index which will identify to what extent the agro-ecosystem of the area is susceptible to climate change, and this will determine the adaptation and mitigation measures to be employed by the farming community towards attaining sustainable agriculture and land management practices, which will in turn determine food security in this era of climate change.

Because agroecosystems play a significant role in climate change, either by mitigating climate change (by carbon sequestration through photosynthesis or soil carbon storage) or exacerbating it (through unsustainable agronomic practices), the time has come to rethink agronomic technologies to cater for comprehensive adaptation and mitigation of future climate change impacts.

Impacts, adaptation and mitigation of climate change pertaining to agroecosystems must be dealt with through more specialised research studies in comparison with the projected climate change scenarios at regional or local level, so as to come up with specific knowledge to address specific climate change problems.

Key words: maize-coffee-banana agroecosystem, climate change, food security, Kilimanjaro region, Tanzania
Willingness to accept (WTA) payments for conservation of ecosystem services along the slopes of Mount Kilimanjaro in Tanzania and Taita hills in Kenya

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Abstract
Payments for ecosystem services (PES) have been proposed as a mechanism to deliver better conservation by linking beneficiaries and providers of an ecosystem service, where providers of services pay those who manage the natural habitats from which services are derived. In developing countries, for instance, these include payments for water provision, ecological tourism, forest carbon (REDD+), crop pollination and delivery of biodiversity outcomes.

The study areas exhibit similar bio-geographical characteristics (such as mountain ranges), with extraordinary ecosystem service values arising from the water towers that supply to the low lying areas, food production, recreation and eco-tourism, habitats and nutrient recycling. However, high population densities in the areas and effects of climate change have resulted into resource use competition between agriculture and biodiversity conservation, which could threaten the sustainability of water provision, food production, community livelihoods, as well as cause many biodiversity losses in the next few years. As human population grows, cultivation and residential areas have expanded into conservation areas. This has created open grassland and shrubs within the confined ecosystems. Therefore, in the course of protecting and conserving these ecosystems and striking a balance between needs and sustainable utilisation, there is need for cooperation between the majority rural poor households and the managing authorities.

A contingent valuation method (CVM) was adopted to elicit what amount of money households are willing to accept as compensation every year to trade-off between conservation of ecosystems and the ongoing destructive socio-economic activities taking place in the areas and how this WTA differs along the attitudinal gradients. The areas were divided into three distinct altitudinal agro-ecological zones, namely the lowland, midland and highland areas. Purposive and simple random sampling was used to select villages/sublocations and households. A total of 352 structured and pretested questionnaires were administered to selected households.

Findings confirmed that mean WTA per year per household increased as one moves from lowland, midland to highland areas, by USD 177.42, to 249.58 to 316.22, respectively. An Independent t-test measure showed a significant mean difference of \( t = 6.387 \) and 0.012 level of significance and \( t = 3.381 \) and 0.067 level of significance between lowland and midland areas, and between midland and highland areas, respectively. These figures implied that mean WTA along the altitudinal gradient of the three agro-ecological zones was statistically different at 10% level of precision.

The study concluded that households residing in highland areas have higher mean WTA as compared to the adjacent lowland areas. Therefore, it is recommended that PES schemes take into account altitudinal gradients when implementing related policies. This will lower costs, in addition to meeting the interests of resource-poor households and the national/global interests on ecosystems and biodiversity conservation around the mountainous critical ecosystems.

Key words: WTA, ecosystem services, altitudinal gradients, households
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