CECAR AFRICA

Climate and Ecosystem Change Adaptation and Resilience Research

6–7 AUGUST 2014

UNIVERSITY FOR DEVELOPMENT STUDIES

TAMALE, GHANA

Conference Program and Abstracts

International Conference on

Enhancing Resilience to Climate and Ecosystem Changes in Semi-Arid Africa

Adaptation strategies for mitigating impacts of climate and ecosystem changes on developing societies

International Conference on Enhancing Resilience to Climate and Ecosystem Changes in Semi-Arid Africa

BACKGROUND

Adaptation strategies for mitigating impacts of climate and ecosystem changes on developing societies

Coping with global climate and ecosystem changes requires developing countries with weak socioeconomic and resource management regimes to devise adaptation strategies. The project "Enhancing Resilience to Climate and Ecosystem Changes in Semi-Arid Africa: an Integrated Approach" aims to develop integrated strategies to build a management base that is resilient to the changes and maintains certain socioeconomic and resource levels. Based on the research on climate change events, ecosystems, and governance in the underveloped, semi-arid northern Ghana, the project suggests that effective adaptation strategies involve addressing the issues of rural development as well as floods and droughts risk management along flat plains and the Black Volta River. These should in turn, alleviate the economic disparity between the north and the rapidly growing southern Ghana.

The project investigates climate and ecosystem changes on major crops through field survey and modelling, assesses impacts of the changes on agriculture and rural development and local capacity to cope with flooding and droughts. The research process further leads to development of integrated strategies that enhance resilience of farming communities in northern Ghana to climate and ecosystem changes and eminent disasters. These strategies will eventually crystallalize into the "Ghana Model", which will be applicable to semi-arid regions across Africa.

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ABOUT THE CECAR AFRICA PROJECT

The "Enhancing Resilience to Climate and Ecosystem Changes in Semi-Arid Africa: An Integrated Approach (CECAR-Africa)" is a project focused on climate and ecosystem change adaptation and resilience research. The project investigates climate and ecosystem changes on major crops through field survey and modelling, assesses impacts of the changes on agriculture and rural development and local capacity to cope with flooding and droughts. The research process further leads to development of integrated strategies that enhance resilience of farming communities in northern Ghana to climate and ecosystem changes and eminent disasters. These strategies will eventually crystallize into the "Ghana Model", which will be applicable to semi-arid regions across Africa. This model will be further discussed in a wider international development and environmental policy arena to contribute to global sustainable development.

The study is ongoing in ten purposely selected rural communities in the Northern and Upper West regions of Ghana. The particular interest in these areas for this research stems from their common ecological setting and socio-economic activities, and differences in exposure to incidence of floods and droughts as well as evidence of high vulnerability to climatic and ecosystem changes. The project was initiated in 2009, and receives financial support from the Science and Technology Research Partnership for Sustainable Development (SATREPS), which is a collaborative programme of the Japan Science and Technology Agency (JST) and the Japan International Cooperation Agency (JICA). As an international project, CECAR-Africa involves seven leading adaptation and resilience research institutions and agencies in Ghana and Japan. The partnering institutions include The University of Tokyo, United Nations University Institute for the Advanced Study of Sustainability, Kyoto University, University for Development Studies, University of Ghana, Ghana Meteorological Agency and the United Nations University-Institute for Natural Resources in Africa. The project also actively collaborates with national, regional and local level governance agencies and departments to undertake its research activities.

Theme 1
Forecast and assessment of climate change impact on agroecosystem
(*Agroecosystem Resilience*)

Theme 2
Risk assessment of extreme weather hazards and development of adaptive resource management methods
(*Engineering Resilience*)

Theme 3
Implementing capacity development programs for local communities and professionals
(*Social Institutions · Technical Capacity Development*)

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7:30 – 8:45 **Registration**

9:00 – 10:00 **Conference Opening and Plenary Session**

Welcome Address:
Prof. Haruna Yakubu
Vice-Chancellor, University for Development Studies, Ghana

Project Leaders Address:
Prof. Edwin A. Gyasi
Professor of Geography, Department of Geography and Resource Development, University of Ghana, Legon

Prof. Kazuhiko Takeuchi
Senior Vice Rector, United Nations University, Tokyo, Japan

JICA Representative

Short Cultural Dance

10:00 – 10:30 **Keynote 1:**
Dr. Joseph Fening
Director of Soil Research Institute, Kumasi, Ghana

10:30 – 11:00 **Keynote 2:**
Dr. GJK Owusu
Chairman, Ghana REDD Committee

11:00 – 11:30 **Keynote 3:**
Prof. Wisdom Apkalu
Associate Professor of Economics, UNU-WIDER, University of Ghana Office, Legon, Accra.

12:00 – 13:30 **Lunch / Poster Presentation (#1-6)**

13:30 – 17:30 **Parallel Sessions A & B**

Session A: Implication of Climate and Ecosystem Changes on Agricultural Production (I)
Session B: Risk Assessment of Extreme Weather Events

18:00 – 19:30 **Conference Reception**

DAY 2

Thursday 7th August 2014

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Session D: Natural Resource Management and Interventions

12:00 – 13:30 **Lunch / Poster Presentation (#7-12)**

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Session F: Capacity Assessment and Resilience Enhancement

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18:00 – 19:30 **Working Dinner**

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Our Soil Africa Foundation, Nigeria

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Session E: Implication of Climate and Ecosystem Changes on Agricultural Production (II)

Session F: Capacity Assessment and Resilience Enhancement

PROFILE OF KEY

PROF. HARUNA YAKUBU

Prof. Haruna Yakubu was born on October 24, 1955, in Tamale, the capital town of the Northern Region of Ghana. He attended Jijiadeyiri Primary School in Wa, Aningazanga Experimental Primary School in Bolgatanga and Kalpohin Middle School in Tamale before proceeding to T. I. Ahmadiyya Secondary School in Kumasi for his secondary education in 1968. He went on scholarship to Kishinev State University, Kishinev in the former Soviet Union where he graduated with an M.Sc degree in Physics and Mathematics in 1984. After returning to Ghana to lecture at the University of Cape Coast for four (4) years, he entered Moldova State University again in Kishinev, from where he obtained his Ph.D in Semiconductor Physics in 1992. He returned to the University of Cape Coast as a lecturer and by dint of hard work rose through the ranks steadily until his present appointment.

At the University of Cape Coast, Prof. Yakubu was actively involved in the administration of the University and occupied various positions including Head of the Department of Physics, Head of the Department of Optometry, Chairman of the ICT Committee and Dean of Students. He was also a member of the UCC Council for three (3) years before becoming the Pro-Vice-Chancellor of the University for four (4) years. He has been lecturing for 26 years.

Between 1997 and 1999, Prof. Yakubu worked as a Research Fellow at the Italian National Agency for New Technology, Energy and Environment-ENEA (Department of Energy-Portici) where he researched extensively into solar cell fabrication techniques and alternative sources of energy. Particularly, he worked on the optical characterization of semiconductor materials and solar modules under Standard Test Conditions (STC) and real operating conditions.

He is a member of many national and international associations including the International Solar Energy Society, Centre for Renewable Studies, Ghana Science Association and the Ghana Physical Society. Prof. has had many honours and awards to his credit and these include: Chairman of Governing Council of Centre for Renewable Energy Studies (CRES), Ghana; Executive Member of the Ghana Solar Energy Society; Member of Governing Council of Foundation for Security and Development of Africa (FOSDA), Ghana; Founding Member of the Energy Research Group, Ghana; and Senior Associate of International Centre for Theoretical Physics (ICTP), Trieste, Italy.

Prof. Yakubu speaks many international languages; English, Russian, Hausa and others. His research interest area is on Energy studies: renewable and alternative sources of energy; solar cell fabrication, installation and sizing of photovoltaic systems; optical studies and characterisation of photovoltaic modules/devices and standards in PV systems.

PROF. KAZUHIKO TAKEUCHI

Prof. Kazuhiko Takeuchi is Senior Vice-Rector of United Nations University, Director and Professor of the Integrated Research System for Sustainability Science (IR3S) at the University of Tokyo. He has served, inter alia, as a chairman of the Central Environment Council, and a vice-chairman of the Food, Agriculture and Rural Area Policies Council, Government of Japan, Editor-in-Chief of the journal *Sustainability Science* (Springer).

Educated and trained as a geographer and landscape ecologist at the University of Tokyo, he engages in research and education on creating eco-friendly environments for a harmonious coexistence of people and nature, especially focusing on Asia and Africa. He leads the *Satoyama* Initiative as well as climate/ecosystem change research in Asia and Africa.

His recent publications include *Satoyama*-Traditional Rural Landscape of Japan (co-edited, Springer, 2003), Rebuilding the relationship between people and nature: The *Satoyama* Initiative (*Ecological Research*, 25, 891-897, 2010), Sustainability: Engaging in global change thorough harmonious adaptation in Asia (co-authored, *Nova Acta Leopoldina*, NF112, Nr. 384, 213-226, 2010), Sustainability Science: A Multidisciplinary Approach (co-edited, United Nations University, 2011), and *Satoyama-Satoumi* Ecosystems and Human Well-Being: Socio-Ecological Production Landscapes of Japan (co-edited, United Nations University, 2012).

PROF. EDWIN AKONNO GYASI

Prof. Edwin Akonno Gyasi holds the BA, MS and PhD degrees in Geography, with specialization in economic geography and agricultural land use. He has had a distinguished academic career largely in the University of Ghana. He retired from that University as a full Professor over 10 years ago, but was re-engaged on a post-retirement contract basis. Professor Gyasi was a Visiting Fellow at: University of Brighton, UK; University of Canterbury, New Zealand; Columbia University, New York. He chairs the Council of the Presbyterian University College in Ghana, and the Board of the Ghana Meteorological Agency. He serves on various other national and international bodies

NOTE SPEAKERS

naian component of the *International Assessment on Climate Change and Peri-urban/ Urban Agriculture in Sub-Saharan Africa* carried out under the START Secretariat, the National Focal Person for the IPGRI project, *Community-based Management of On-Farm Plant Genetic Resources in Arid and Semi-Arid Areas in Sub-Saharan Africa.* He led and co-ordinated the West African component of the UNU research project, *People, Land Management and Environmental Change (PLEC)*, and was the National Programme Co-coordinator of the follow-on GEF-funded project, *Sustainable Land Management for Mitigating Land Degradation, Enhancing Agricultural Biodiversity and Reducing Poverty (SLaM) in Ghana.* His Research centres on natural resources management with emphasis upon: environmental change; participatory methodologies; locally adapted agricultural land use practices in rural and peri-urban contexts. Professor Gyasi has published widely and carried out many consultancy works. He is married, and has four children.

DR. JOSEPH FENING

Dr. J O Fening is a Chief Research Scientist and Director of the CSIR-Soil Research Institute, Kumasi. He holds a PhD degree in Soil Science with specialization in Soil Microbiology. Dr. Fening has accumulated over 20 years of research, experience in soil biology and biochemistry. His research interest and activities are wide, but his current interests are particularly in the fields of Climate Change, Biological Nitrogen Fixation (BNF), Biotechnology, Integrated Nutrient Management, Organic matter and the use of Biofertilizers in sustainable agriculture.

Dr. Fening has also been a part time lecturer at the Kwame Nkrumah University of Science and Technology, Kumasi, Crop Science Department since 2000, teaching at both the undergraduate and post graduate levels. His research activities have led to the publication of over 60 articles in international scientific journals, books and conference proceedings. He has also managed several international funded research projects and has substantial experience in institutional management. Dr. Fening belongs to several professional bodies such as the UNU College of Research Associate and AABNF. He is a consultant to the UNDP, FAO, and serve on several boards including the National Fertilizer Council.

MR. GJK OWUSU

Currently Co-Chair of Ghana's National REDD + Working Group, Mr. Owusu is a former Director of the Institute (now Faculty) of Renewable Natural Resources, Kumasi, Ghana. He has done several consultancy works in the areas of forest policy and legislation.

He is a forester, educated at the University of Edinburgh, Scotland, and the Commonwealth Forestry Institute, University of Oxford, a Fellow and first President of the Ghana Institute of Foresters. He has served for a term as a Member of the Board of the Ghana Forestry Commission and a member of the National Energy Board. His research interests have been in Forestry Policy and Legislation.

PROF. WISDOM AKPALU

Prof. Wisdom Akpalu is a Research Fellow with UNU-WIDER and currently collaborating with the University of Ghana on a PhD program in Development Economics. Prior to joining WIDER he was Associate Professor of Economics at State University of New York (SUNY) - Farmingdale, and the Chair of the Economics Department. His research interest is within the field of natural resource management in developing countries, and economics of crime and punishment. He has published over two dozen journal articles, written books chapters, and several peer reviewed working papers and discussion papers. He is an active reviewer of over two dozen journals in economics. He is currently a resource person for CEEPA and a guest resource person at the AERC. He has consulted for a number of reputable organizations including the ILO, AfDB, and The World Bank.

Wednesday 6th August 2014

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ABSTRACTS

SESSION A

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Implication of Climate and Ecosystem Changes on Agricultural Production (I)

A1

The socioeconomic impacts of climate change on the livelihood and adaptation strategies of smallholder farmers in the Upper White Volta Basin of Ghana

J. Amikuzuno*[1], I. Hathie[2], S. G. Adiku[3], D. S. Maccarthy[3]

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Abstract

Climate change and agriculture affect each other. Climate change affects the agroecological and growing conditions of crops and livestock. Conversely, agriculture engenders climate change via its role in greenhouse gas emissions and carbon sequestration. In Sub-Sahara Africa's (SSA) rain-fed agricultural systems, climate change impact on precipitation and temperature is the major cause of crop failure and low yields; even though these are often attributed to small farm sizes; and low use of fertilizer, improved seeds and pesticides. What however, is the empirical evidence of the socioeconomic impacts of climate change on the livelihood and adaptation strategies of SSA's smallholder farmers? In this study, we use the trade-offs analysis minimum data (TOA-MD) model to estimate climate change impacts and adaptation strategies of 300 farmers in the upper White Volta of Ghana. The analysis encompasses three objectives: i) determining the sensitivity of current agricultural production systems to climate change without adaptation; ii) estimating the impact of climate change on future agricultural systems following the evolution of production systems with changes in the agricultural sector not motivated by climate change; and iii) ascertaining the benefits of climate change adaptation. We implement the TOA-MD with simulated maize, millet and groundnut yield from the APSIM and DSSAT models; for current (1980-2009) and future (2040-2069) climates, and under five climate scenarios. The findings reveal varying levels of negative impacts of climate change on farmers' net per farm revenues, per capita incomes and poverty rates assuming climate change without adaptation. When adaptation is accounted for, most farmers gain by as much as 76%, per capita incomes increase and poverty rates decline. The benefits of adaptation thus prove that climate change is not necessarily bad, but possibilities exist for farmers to gain from the phenomenon given the right measures and incentives, and the adoption of climate-resilient strategies.

Key words: *Adaptation, Climate change, Ghana, White Volta basin*

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3. Dept of Soil Science, and the Soil and Irrigation Research Centre, University of Ghana, Legon, Ghana

A2

Assessing the impacts of climate shocks on the performance of farm activities and adaptation policy responses

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Introduction

Agriculture in Benin faces more risk and uncertainty due to climate variability and change through its high dependence on weather conditions. The first Millennium Development Goal (MDG) is about eradicating extreme poverty and hunger and should be attained by 2015, but the current situation suggests that it will be hard for Benin to achieve it. The situation is becoming worse, due to climate shocks which are exacerbating it. Thus, this research aims to assess the impacts of climate shocks on farming and to simulate adaptation policy responses.

Materials and methods

Area of the study and data

The study focuses on farmers of the Niger basin that covers 37.74% of Benin. The basin is located in the extreme north of the country and more specifically between latitudes 11° and 12°30' N and longitudes 2° and 3°20'40 E and has an area of 43,313 km^2. It covers five agro-ecological zones (AEZs) (wholly and partially) out of the eight of Benin.

The data comes from the household survey which was implemented within the Niger basin of Benin in the 2012-2013 agricultural year on 545 farm households and from literature on the topic. Three-stage random sampling was used: first, municipalities within each AEZ, second, villages within selected municipalities and last, farm households within selected villages. AEZ V was disregarded, because only one of its municipalities is located within the basin.

Model

This study uses a recursive dynamic Mathematical Programming (bio-economic modeling) by relying on the Agricultural Household Model theory (AHM). The model is run for the planning horizon of ten future years and market imperfections are included (labor and credit markets). Climate shocks are incorporated through the probabilities of occurrence of the states of nature relative to the rainfall conditions: good, normal, bad, disastrous due to floods, and disastrous due to droughts. The objective of the farmers is to maximize the discounted expected cash income from cropping, livestock, and the off-farm activities. Risk is taken into account by Telser's Safety First method (Telser 1955).

Results and discussion

Farmers produced mainly during the rainy season. 94.5%, 56.9%, 47.7%, 41.3%, 40.7%, 33%, 31.4%, 31.2% and 19.1% of them produced maize, millet, yam, sorghum, cotton, bean, soya bean, rice and cassava respectively. In terms of irrigated crops during the dry season, the major produces were rice (2.8%), onion (1.8%), pepper (1.3%), tomato (0.6%) and okra (0.2%). 43.3%, 55.6%, 42.8%, 65.1% and 4.2% of the households owned cattle, goat, sheep, poultry, and other animals respectively. As how climatic shocks affect farmers depends on their specificities, farm households were clustered into homogenous groups. Two clusters are built in each of the four AEZs: (i) less poor with weak social capital farm households, (ii) poor with strong social capital farm, (iii) poor with weak social capital, (iv) less poor with strong social capital, (v) less poor with weak social capital, (vi) poor with weak social capital, (vii) less poor with weak social capital, and (viii) poor with weak social capital respectively.

Simulations of the impacts of climate shocks and of extreme events

The simulations show a drop in farm income due to climate shocks from 17.43 to 69.48 percent compared to the baseline scenario. Farmers of agro-ecological zone II will be the most affected by climate shocks, followed by agro-ecological zones III, I and IV. Regarding extreme events, the bad rainfall conditions from the baseline scenario were converted into extreme events (disastrous due to floods and disastrous due to droughts), under the assumption that the occurrence of extreme events will increase to the detriment of the bad rainfall conditions. First, half of the bad rainfall conditions were converted into extreme events (first scenario), and second, the overall bad rainfall conditions were transformed into these events (second scenario), and this holds for floods and for droughts. The results reveal that floods and droughts affect negatively farming. In the case half of the bad rainfall conditions will be converted into floods, the poor with weak social capital farm households of AEZ II will be the most affected. The same category of farm households will be the most affected when all the bad rainfall conditions are converted into floods. Regarding droughts, the poor with strong social capital farm households of AEZ I will be the most affected.

Adaptation scenarios

The adaptation policies fall into a range of four actions: (i) improve irrigation since agriculture in Benin is mostly rain-fed and is constrained by the water availability[1], (ii) better access to credit due to the importance of liquidity in farming, (iii) research and development which is supposed to increase yield level[2], and (iv) better access to the labor market[3]. They contribute to coping with the adverse impacts of climate shocks on farm income. The combination of irrigation in cotton production and the possibility to find available labor, to be hired, appears the best measure, that mitigates the adverse effects of climate shocks, followed by the correction of the labor market imperfection about 100% combined with a perfect credit market, a correction of 100% of the imperfection in the labor market, an increase of 25% of the maize, sorghum, millet and rice yields and lastly by credit. The results are consistent with those of previous studies such as those of Lamb (2003), and Fofana (2011).

Discussion in terms of food and nutrition security

The situation of the farmers in terms of food and nutrition security will be affected if any action is taken. As climate shocks are predicted to impact adversely farming, food availability and access will be affected through a decrease of the part of the production devoted to self-consumption and cash income that should serve as means to get additional food. Moreover, farmers could not be able to meet dietary diversity. The decrease of cash income will make things more difficult to the farmers in terms of being able to afford health care fees.

Conclusion

Farm activities will be negatively affected by climate shocks and extreme events. The impacts could be mitigated by relevant adaptation policies. However, the success of the adaptation policies highly depends on the ability of policymakers to implement them.

References

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- Telser LG (1955): Safety First and Hedging. The Review of Economic Studies 23 (1): 1-16.

1. Transform cotton rain-fed fields in supplementary irrigated fields for simplicity.
2. 25% improvement of maize, sorghum, millet and rice yields.
3. Correct labor market imperfection about 100% from the baseline scenario.

A3

Sensitivity of cereals production in smallholder farmers' fields to climate change; the case of Upper White Volta Basin of Ghana

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Introduction

Climate change is increasingly becoming a major subject of study globally. Its effects are expected to impact differently in different sub regions with adverse impacts to be more pronounced in low input systems (MacCarthy and Vlek, 2012; Van Ittersum *et al*., 2003) in the tropics. Crop production in Northern Ghana is characterized largely by low input farming and is dependent on rain-fed conditions. With the projected variability that is to be associated with climate change, smallholder farmers are likely to be adversely impacted. There is therefore the need to characterize the potential effects in this region and access possible adaptation measures to address any negative impact. Studies of this kind in this region are limited and restricted to the use of a typical field to represent the study area. This study simulated multiple fields with associated study assessed the sensitivity of current crop production systems to climate change and assessed possible benefits of adaptations and improved soil fertility management to mitigate impacts of projected future climate change on cereal production.

Materials and Methods

The study region is Navrongo, located in the Upper East Region of Ghana. Agricultural Productions Systems sIMulator (APSIM) version 7.4 calibrated and validated for maize (Fosu-Mensah et al 2013) and millet (Akponikpe et al 2010) were used. The crop simulation model was used with weather data from 5 General Circulation Models (GCM- CCSM4_E, HadGEM2-ES_K, GFDL-ESM2M_I, MPI-ESM-MR_R and MIROC5_O) with simultaneous simulation of multiple farms, multiple management regimes and multi-years. Information on farmers management practices were obtained from a house hold survey conducted in 2012 and used as input data for the model. Climate projections for the near future (2040 – 2069) by 5 GCM and baseline climate (1980 – 2000) data (with daily temperature, rainfall and solar radiation), were used to simulate the yield of millet and maize under (i) baseline climate using baseline cultivar; (ii) projected future climate with baseline cultivar; (iii) projected future climate with virtual cultivar; (iv) projected future climate with the use of 45 kg N ha^{-1}. Each of the 30 years simulation under each scenario was considered as replications. Analysis of variance was used to compare grain yield under the various scenarios. Coefficient of variation = $(std/m)*100$, where *std* and *m* are standard deviation and mean yield respectively and percentage yield changes = $(PS\text{-}BL/BL)*100$, where *PS* and *BL* are mean yields obtained under projected climate and baseline climate respectively were also calculated. Sensitivity analysis of weather parameters was also done.

Results and Discussions

Simulated average baseline yield of millet was 318 kg ha^{-1}. Maintaining the current production systems under climate change scenarios produced millet yields of between 282 and 322 kg ha^{-1} representing yield reductions of 9% and 12 % for GCMs CCSM4 and HadGEM2-ES_K respectively. The GCM GFDL-ESM2M_I produced similar yields compared to the baseline climate while GCM MPI-ESM-MR_R produced an increase in yield over that of the baseline. For maize, baseline yield of 942 kg ha^{-1} was simulated. The effect of projected climate change on maize was marginal with yield reductions of 1 and 4 for GCMs MIROC5_O and HadGEM2-ES_K respectively while GCMs CCSM4_E produced 2 % yield reduction. As with millet, GCMs GFDL-ESM2M_I and MPI-ESM-MR_R produced increased yield, though not significantly different from that of the baseline. Differences in yield observed among GCMs could largely be due to differences in projected temperature, rainfall amounts and the length of the growing season. A sensitivity analysis of the weather parameters (temperature, rainfall and CO_2) indicated that yields of both cereals are most sensitive to temperature changes with increasing temperature resulting in decreasing grain and biomass yield due to accelerated phenology, thus, reducing time for resource capture (Anwar et al, 2007). The sensitivity to temperature varied depending on soil type and management practices, with fields with poorer soils being more negatively affected. Even though the use of virtual cultivars (adapted to heat and drought stress) resulted in increases in yield of between 25 and 53 % for millet and 7 to 12 % for maize across GCMs, the use of 45 kg N ha^{-1} alone with the use of the base cultivar resulted in yield increases of between 203 to 214 % for millet, and between 325 and 356 % for maize.

The uncertainty associated with yield production reduced with the use of the virtual cultivar and use of mineral fertilizer for both crops (**Table 1**). Thus, though climate change poses a threat to food security in this region, the threat can be significantly reduced by using adapted crop cultivars. If mineral fertilizers can be made accessible to smallholder farmers, current crop yields can be more than doubled even with climate change effect.

Table 1: Simulated variability in the yield of millet and maize under different scenarios in the smallholder systems in upper east region of Ghana

GCM	Millet (CV - %)			Maize (CV - %)		
	CS+CC	AC+CC	F+CC	CS+CC	AC+CC	F+CC
CCSM4_E	36	21	5	66	66	10
GFDL-ESM2M_I	27	16	5	63	64	8
HadGEM2-ES_K	36	22	5	65	65	10
MIROC5_O	38	23	5	65	66	10
MPI-ESM-MR_R	30	19	7	64	64	9

CS, CC, AC, F are current system, climate change, adapted cultivar and fertilizer respectively

Conclusions

The productivity of maize and millet are sensitive to climate change. The use of the virtual cultivar will reduce the sensitivity of current crop production systems to climate change. Improved soil management yielded more benefits under climate change than the use of virtual cultivar. In light of projected climate change and its effects, efforts aimed at improving soil fertility needs to be given more attention as a strategy to improve food security.

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A4

Effects of climate change on tree species population and dispersion pattern within household farmlands and open parklands in the Talensi area of northern Ghana

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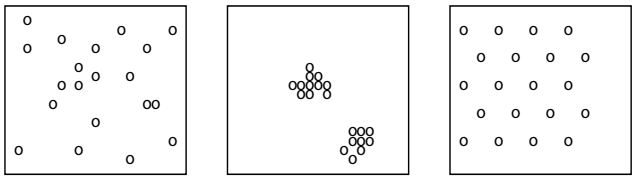
Introduction

Ghana is bedeviled with issues of dwindling natural resources in the area of tree species. This problem is particularly more serious in parts of the country that are known to be experiencing the impact of desertification and climate change. According to the IPCC (2005), Climate change simply refers to increase or decrease in the average precipitation caused by land-use changes and the anthropogenic increase in the concentrations of greenhouse gases, particularly carbon dioxide (CO_2) in the earth's atmosphere.

Population size generally refers to the number of individuals present in the population, and is self-explanatory. Density refers to the number of individuals in a given area. For ecologists density is usually a more useful measure. This is because density is

standardized per unit area, and therefore, can be correlated with environmental factors or used to compare different populations.

Biodiversity conservation relies on understanding how plant resources are distributed across complex landscapes and modified for human livelihoods (Cunningham, 2001). The distribution pattern of a tree species population can be described in three possible types (Random, Uniform or Clumped). In a random distribution pattern, the locations of all individuals are independent of each other. In a uniform distribution pattern, the occurrence of one individual reduces the likelihood of finding another individual nearby. In a clumped distribution pattern, the occurrence of one individual increases the likelihood of finding another individual nearby. In this case, individuals tend to form groups or clumps (Sokal & Rolf, 1981).



Random Clumped Uniform

This study was aimed at measuring how rich and abundant individual woody tree species are in the Talensi area and to determine their dispersion pattern in both household farmlands and open parklands.

In most cases it is either difficult or simply not possible to census all of the individual tree species in a target area. The only way around this problem is to estimate population size using some form of sampling technique. So far, in many parts of the world, very few attempts have been made to analyze the patterns of plant species diversity in the human dominated landscape, especially in relation to time scale (Carey *et al.,* 2007; White *et al.,* 2006). These type of data from studies like this are necessary for climate change impact assessments (measuring effects of disturbance) and restoration ecology (restoring ecological systems). The Talensi area of Northern Ghana falls within the Talensi District of the Upper East Region of Ghana.

Materials and methods

In this study, stratified random sampling was employed in selecting communities, household farmlands and open parklands. Fifteen (15) communities were randomly selected for the study. Within each community, five (5) household farmlands and two (2) open parklands with square land quadrats of 10000m^2 were sampled and data collected. In all, a total of 105 quadrats where sampled for the study.

Species Richness and Species Abundance was used in estimating population size whilst the Shannon-Weiner Index was as a measure of Diversity. The variance (s^2) to mean ratio was used to measure Dispersion Pattern. (s^2/mean > 1.0 = clumped distribution, s^2/mean = 1.0 = random distribution and s^2/mean < 1.0 = uniform distribution). A test statistic (t) was used to test for significantly different in the distribution pattern. $t = \{(s^2/\text{mean}) - 1.0\} / \{\sqrt{2/(n-1)}\}$

Results and discussion

In all the study area for both household farmlands and open parklands, a total of 78 individual woody plant species were identified and studied. The most abundant woody trees species (>10 species) in household farmlands were: *Adansonia digitata* L., *Azadirachta indica* A. Juss, *Diospyros mespiliformis* Hochst. Ex A. Rich, *Ficus trichopoda* Baker, *Jatropha Curcas* L., *Lannea acida* A. Rich, *Mangifera indica* L., *Parkia biglobosa* R.Br. ex G. Don and *Vitellaria paradoxa* Gaerfn. F.

In the open parklands, the most abundant species (>3 species) were: *Acacia sieberiana* DC., *Anogeisus leiocarpus* (DC) Guill & Perr., *Azadirachta indica* A. Juss., *Combretum collinum* Fresen, *Diospyros mespiliformis* Hochst. Ex A. Rich, *Ficus trichopoda* Baker, *Lannea acida* A. Rich, *Tamarindus indica* L., *Vitellaria paradoxa* Gaerfn. F. *and Ziziphus abyssina* Hochst. ex A. Rich.

Species Richness; is the simplest of all the measures of subspecies diversity. The number of species per sample in a location is a measure of richness. The more species present in a sample, the 'richer' the sample. It does not take into account the proportion and distribution of each subspecies within a zone.

Species Abundance; gives an indication of the total number of individual species present in a given location. Household farmlands were more species rich than open fields. For species abundance household farmlands was far higher (657) than open parklands (189). Diversity (H) based on the Shannon-Weiner Index showed slight difference for both fields 1.15 and 1.34 for household farmlands and open parklands respectively. The species diversity which takes into account the species richness for both fields was not significantly different ($p>0.05$) from each other. To the ecologist, this shows that though household farmlands are more abundant with species, they are not significantly different in diversity.

Climate Change analysts are more interested in the spatial distribution of species populations because it provides information about the social behavior and/or ecological requirements of the species.

Values obtained from the variance (s^2) to mean ratio of household farmlands and open parklands were greater than 1. The results therefore shows that dispersion pattern of tree species in both land types could be described as clumped distribution. In a clumped distribution you should find some quadrats containing a large number of individuals and many quadrats that are empty. In a clumped dispersion, the occurrence of one individual increases the likelihood of finding another individual nearby. A test statistic showed an absolute value of 3.26 and 3.27 respectively, for household farmlands and open parklands. These value show that the distribution pattern is significantly different from the other patterns (random and uniform) since the value is greater than 1.96 (at a confidence level of 95%).

Conclusion

Effective management of natural resources can ensure that these resources not only survive, but also increase while being used rationally, thus providing the foundation for sustainable development and for a stable national economy (Steiner *et al.,* 2004).

Table 1. Species Diversity in Household Farmlands and Open parklands

Land Type	Richness	Abundance	Diversity (H)
Household Farmlands	60	657	1.15
Open Parklands	49	189	1.34

Table 2. Estimates of Variance for Dispersion Pattern of Species Abundance

Field	Mean	Variance (S^2)	s^2/mean	Indicated pattern	t	Significant (Yes/No)
Household farmlands	164.25	1473.18	8.97	Clumped	3.26	Yes
Open parklands	47.25	425.18	8.99	Clumped	3.27	Yes

A total of 78 individual woody plant species were identified and studied. The study revealed that household farms lands are more species rich and abundant than open parklands. Both fields were not significantly different in-terms of species diversity. Dispersion pattern of tree species population in the Talensi area in both land types is described as a clumped, this indicates a large variation in species numbers between the different suburbs of the study area.

This study of tree species densities and dispersion pattern has provided important information about rarity and commonness of species in the Talensi area. The ability to quantify diversity in this way is an important tool to determine the level and effect of climate change on our tree species.

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A5

Towards sustainable land and biodiversity management in traditional society of savannah ecological zone

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Abstract

In recent years, the value, use and management of biological resources in traditional societies have widely been recognized as opportunity for sustainable biodiversity management. In traditional localities, strong connections exist between indigenous people and their natural environment. Understanding this connection is fundamental to enhancing knowledge on local communities' biological resource utilization and how that affects biodiversity management. In this study, we examine how local community's dependence on biological resources and management practices affects biodiversity. Hence, land use and biodiversity survey was conducted in the savannah regions of Northern Ghana; specifically in the Tolon district covering Yoggu, Cheshagu, Kpalgun, Fihini, Daboshie and Zagua communities. Questionnaires were administered to individual households and information solicited on patterns and practices of biological resource use. In-depth interviews were conducted with selected community leaders and traditional heads while group meetings

with select community members were conducted; both of which explored the changing use land and management practices and impacts on biodiversity. Key community biological resources were mapped out and analyzed to assess the extent of their ecological vulnerability. Findings indicate that biodiversity loss is high in the study communities to which the communities are willing to pay high cost in preservation of biodiversity. Findings also show that though the potential of traditional natural resources management for effective biodiversity conservation is vast, the sustainability of these resources is seriously threatened. Extensive agricultural land use conversion and poor farming practices remains the direct drivers to biodiversity change. In addition, break down in the belief systems, overharvesting of wood resources, population increase, limited land access, drought and bush fires combine to push most biological resources to extinction. We recommend that, for sustainable management of biological diversity, there is the need for communities to preserve and maintain reserves (sacred groves) as these remain the only store of biodiversity resources. Again, supporting communities to establish and maintain woodlots particularly on degraded lands as well as reforestation programmes could reduce the burden on wooded species. To strengthen local institutions to support sustainable management of biodiversity, public education and awareness creation, and integration of traditional and modern knowledge system are proposed as necessary for sustainable management of biological resources.

A6

Reducing woody species composition of riparian forests in farmlands in the moist savannas of Ghana: implication on managing risks to climate change impacts

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Introduction

In savanna agricultural landscape, riparian forests (RF) are resilient to climate change impacts as the continuous supply of moisture coupled with the topographic heterogeneity and closed linear canopy limit grassy fuel loads, increase relative humidity, decrease temperature and wind speed to reduce fire risks (Sambare *et al.,* 2011; Azihou *et al.,* 2013). RF are ecologically important as they protect farmlands from flooding, drying and sedimentation. They also serve as habitat for fauna such as birds, insects and other organisms that are essential for crop pollination, seed dispersal and nutrient cycling. Due to these functions and many others, RF are protected by international conventions, national laws and policies (McCracken *et al.,* 2012; Gray *et al.,* 2014). In spite of this, RF are being cleared for agricultural activities, resulting in the loss of woody species composition and linked functions. Globally, land areas dedicated to agricultural production are much greater than protected areas, and therefore agricultural landscapes cannot be excluded from biodiversity conservation (Gray *et al.,* 2014). With appropriate management, agricultural landscapes can contribute to the preservation of biodiversity and delivery of ecosystem services (McCracken *et al.,* 2012). This study compares riparian woody species composition in farmlands and that in protected area using the Afram River located in the Guinean forest-savanna transition of Ghana as case study. It also assesses the implications of the differences in woody species composition to management of risks to climate change impacts. This would provide baseline for appropriate management of biodiversity on farmlands.

Materials and methods

The study was conducted along the Afram river in protected area (PA; Kogyae Strict Nature Reserve) and on farmland (FA) in the Guinean forest-savanna transition of the Ashanti region of Ghana (**Fig. 1**) (Ofori *et al.,* 2014). Crops cultivated on farmlands are predominantly maize and rice. The average annual temperature and precipitation are 27°C and 1400mm respectively. The topography is flat to gently undulating with small areas of steep slopes occurring locally. The soil is well-drained sandy loam (**Callo-Concha *et al.***, 2012). Prior to field sampling from October-December (2013), woody vegetation within the river catchment was mapped with ALOS AVNIR image of 27 February 2011 (resolution=10m) using maximum likelihood classification algorithm at an accuracy of 89% (**Fig. 1**) to facilitate inventory with stratified randomized design in FA and PA. Whether in PA or FA, the rivercourse was divided into 3 blocks, each of length (6-8km). The woody species (diameter at breast height ≥ 5cm) inventory was conducted in sixty random rectangular plots (500m^2 per plot), 30 each in PA and FA and 10 per block. Shannon-Wiener Index (SWI) was calculated as a measure of woody species diversity (Natta *et al.,* 2003). Woody species density was calculated per plot of 500m^2. Student's t-test was used to estimate the significance of the differences of SWI and density between the PA and FA. Significance level (p) for comparison was fixed at 0.05 for a degree of freedom (df).

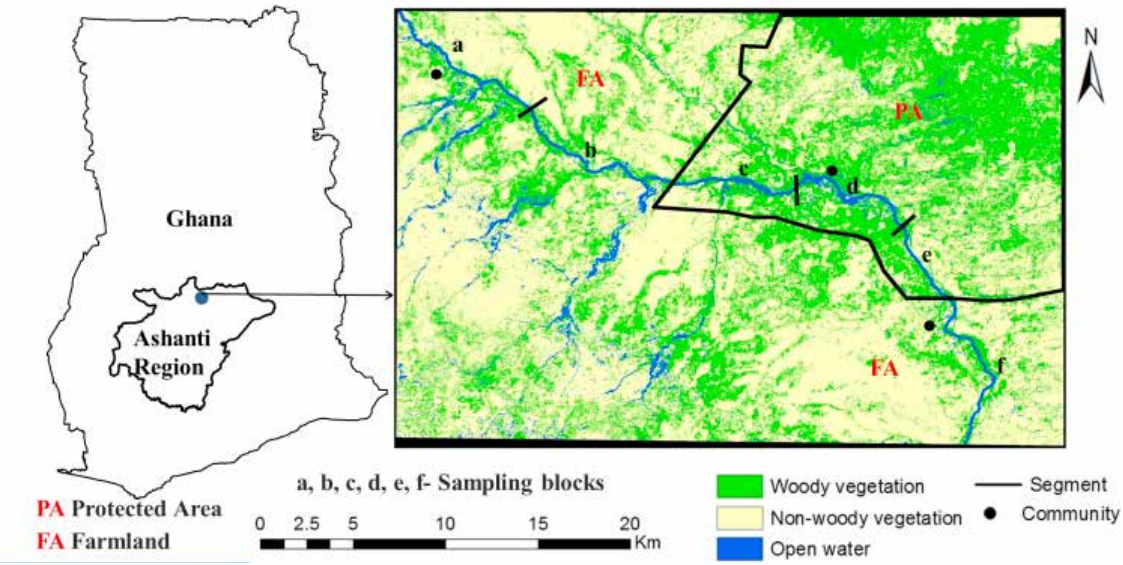

Fig. 1 Location map of the research area in the Ashanti region of Ghana

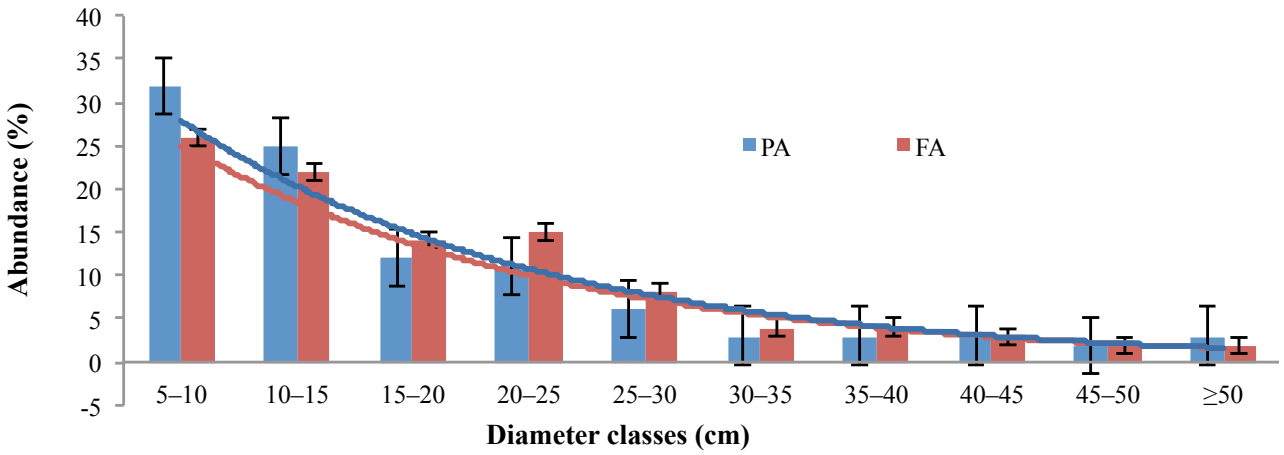

Fig. 2 Diameter class distribution of individuals ≥5 cm dbh in RF in PA and FA

Results and discussion

A total of 63 woody species belonging to 24 families were recorded along the Afram river in both PA and FA with three most species rich families being Papilionaceae (14%), Rubiaceae (14%) and Caesalpiniaceae (13%). This finding testifies to the importance of RF in maintaining high species richness, due to the intensity and frequency of floods, small-scale variation in topography and soil of the riparian area that create a diversity of habitats which allows a wide variety of species to co-exist (Sambare *et al.,* 2011). The number of species in this study was higher than that reported along the Comoé (54) and Ouémé (50) rivers located in the Sudano-Guinean savannas of Cote d'Ivoire and Benin respectively (Natta & Porembski, 2003).

The total number of specimen recorded along the Afram river was 1232 with 817 in PA and 415 in FA. Thirty four species were common to both PA and FA. Twenty four and 5 species were found exclusively in PA and FA respectively. Examples of the species found only in the PA were *Albizia glaberrima* (2%), *Albizia zygia* (1%), *Alchornea cordifolia* (1%) *etc.* The five species recorded exclusively in FA only were *Acacia macrostachya* (1%), *Anthocleista nobilis* (1%), *Azadirachta indica* (1%), *Canthium vulgare* (2%) and *Raphia hookeri* (1%). Some of the species common to the PA and FA were *Pterocarpus santalinoides* (11%), *Mitragyna inermis* (11%), *Cynometra megalophylla* (7%) *etc.* In all, the number of species reduced from PA (58) to FA (39) contrary to our expectation as RF is protected by law in Ghana. Shifting cultivation, farm expansion and intensification may have caused the removal of the woody species in FA (Ceperley *et al.,* 2010). It was therefore, not surprising that the mean SWI of the riparian woody species on FA (3.1±0.4) was significantly lower ($t=7.09$, $df=58$, $p<0.0001$) than the PA (3.8±0.3). In spite of this, the SWI in both FA and PA were within the range (2.4 to 5.4) reported in other savannas of West Africa (Natta & Porembski, 2003; Natta *et al.,* 2003).

The diameter class distribution of woody species of RF on FA was similar to that in PA as both showed a reversed "J" shaped curve (**Fig. 2**). This finding meant that the RF on FA still has the potential to regenerate naturally and face no danger of extinction as observed in other studies (Sambare *et al.,* 2011). Nevertheless, the significant reduction (t=12.4, df=58, p<0.0001) in the mean density of woody species from the PA (27.2±4.8) to FA (13.8±3.4) is likely to increase soil moisture loss and increase risks of RF on farmlands to fires (Azihou *et al.,* 2013).

Conclusion

Riparian forests in this part of Ghana contribute to the conservation of high woody species composition. Nevertheless, the decline in the woody species composition from protected area to farmland may be increasing the risks of riparian forests in this area to climate change impacts. Managing the risks will be difficult unless conscious effort is made to retain woody species on farmlands, or area excluded from farming for recovery.

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A7

Bushfires and agroecosystems change in northern Ghana: insights from rural households in the Wa West District, Upper West region

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1. Introduction

Fire, regarded as one of mans' earliest discoveries and tools has been extensively utilized in the modification of the natural environments for centuries. It remains integral in land management and livelihood systems of households and communities across socio-ecological regions. It is argued that, the evolution and present nature of the savanna ecosystem in Africa is a reflection humans' frequent use of fire on the landscape (White, 1983; Stott, 1991; Whelan, 1995; Laris, 2002; Mistry, 2002). Thus, the savanna agroecosystem is characteristically noted for the prevalent use of fires by inhabitants. The importance and dependence on fire by rural households in the savanna ecosystem is noticeable in land clearing, herding, hunting, and fuelwood harvesting (Appiah et al., 2010, Prasad et al., 2008). Notwithstanding the importance of fire to rural economies, its use—regulated and unregulated— has been empirically found to be detrimental to the social, economic and physical milieu. Thus, bushfires may well be referred to as the deliberate or accidental burning of vegetation for various reasons. Bushfires have been found to be primary contributors to the global increase in greenhouse gas emissions (IPCC, 2007; Prasad et al. 2008). In the tropical savanna regions of many countries including Ghana, perennial bushfires play a fundamental role in the degradation and decline of essential ecosystem services (FAO, 2000; EPA, 2002; Kalame et al., 2009).

In Ghana, bushfires are known drivers of environmental change across the six agro-ecological zones since the droughts of 1983/84 (EPA, 2002; Gyasi et al. 1995; Blay *et al*., 2008). Available data on the effects of the 1984-85 bushfires on the various socio-ecological zones of Ghana shows that the Sudan

and Guinea savanna zones experienced the most negative impacts (EPA, 2002).Within the savanna agro-ecological zones of northern Ghana, the focal area for this study, annual bushfires is widespread and is negatively impacting on the social, economic and physical conditions of inhabitants. The savanna regions' unique grassland ecosystem coupled with its distinct climatic regimes—short wet and long dry seasons— makes the landscape suitable for fire utilization. Consequently, the area is highly vulnerable to human and nature-induced bushfires, thus resulting in high depletion of soil organic matter and nutrients, loss of vegetative cover, and the decline and scarcity of provisioning ecosystem services (EPA, 2002). Ultimately, the productive capacity of agriculture lands in the regions have been reduced greatly, thus worsening the poverty and food insecurity situation among households (Sonsgore, 2006; Yahaya and Amoah, 2013).

While a number of studies have examined the interconnections between bushfires and savanna agroecosystem, the focus has often been on the social and biophysical implications on households and communities (Fairhead and Leach, 1998; Mistry, 2002, Laris, 2002; Appiah et al. 2010; Yahaya and Amoah, 2013). Few studies adopt an integrated approach to evaluate the vulnerability of the physical and social components of ecosystems to the effects of fires. An integrated study is expected to provide findings that can aid local, regional and national governments in pragmatic decision-making. Against this backdrop, this study utilizes a multidisciplinary approach combining socio-economic and physical environmental data to examine the influence of bushfires on savanna agroecosystem changes in northern Ghana. By this, the study identifies households and other stakeholders' perceptions of the causes, effects and experiences of bushfires in their livelihood activities.

2. Materials and Methods

2.1 Study Area Description

The Wa West District is located in the Upper West Region of Ghana approximately between longitudes 40°N and 45°N and Latitudes 9°W and 32°W. It lies in the Sudan savanna agro-ecological zone with a generally undulating landscape averaging a height of between 180m and 300m above sea level. With a distinctive uni-modal rainfall pattern, communities in the district enjoy two marked seasons. The rainy season usually begins in May and ends in September with the dry season beginning in October and ending in April. Average monthly maximum temperature is 33°C while the daily highest is 35°C. Subsistence farming involving crop production and animal rearing is the dominant socio-economic households among. The Black Volta River is an important water body supporting farming and other household needs including fishing. This study focuses on three villages; Zowayili, Bankpama and Baleufili, which are part of carefully selected sites for the ongoing international collaborative research on climate and ecosystem change in northern Ghana. These communities are characterized by annual incidence of floods and droughts which often impacts negatively on social, economic and environmental sustenance of households.

2.2 Methods

This study started with a reconnaissance survey of the study sites in August, 2013 during which household questionnaires were pretested and revised. The finalized survey was conducted on a sample of 90 randomly selected households (30 in each study site). Questions asked included the use of fire, causes, frequency, effects, and prevention techniques for bushfires. The sample frame included all households in each of the study sites. Key informant interviews made up of hunters, herdsmen and lead farmers were identified and interviewed with the help of community leaders. Group meetings composed of key informants were also held in each study site to validate household and individual responses from earlier interviews. Field visits to farms, conserved areas and other places of interests were undertaken and photographs taken.

Land cover change detection assessment involved the use of Landsat TM images of 1991, 2001 and 2011. Bands 5, 4, and 3 were combined (Red-Green-Blue, RGB). These images were mosaicked to size using the co-ordinates of the Wa West district. Reclassification resulted in five main landuse and land cover (LULC) classes—water body, vegetation, bareland, cultivated/farmlands and built-up areas. Total coverage for each LULC was extracted. Groundtruthing with the aid of a Global Positioning System was undertaken.

3. Results and Discussion

The use of fire outside the homes of respondents was found to be extremely high with no significant differences being observed in the study sites. Interviewees mentioned a number of reasons behind their use of fire to include killing pests and weeds, clearing bush for farming, collecting honey, hunting for bushmeat and pasture regrowth. The uncontrolled use of fire for these varieties of human–related activities especially in drought season was mentioned as the most immediate causes of bushfires. Observed negative changes to biodiversity and ecosystems and its provisioning services were cited as the effects of episodic bushfires. Principally, respondents alluded the shea tree's (*Vitellaria paradoxa*) declining flowering and fruiting capability to frequent exposure to heat shocks from bushfires. Change detection analysis from land cover maps showed a significant decline in vegetative cover between 1991, 2001 and 2011. Although this study cannot explicitly blame the loss in vegetative cover on bushfires, land cover change results provides a significant proof of anthropogenic role in the area of which bush burning is well mentioned by households.

Respondent's memories of the destructive effects of bushfires on their livelihoods seem to have little influence on their utilization of fire. Despite local communities' perception of bushfires as a seasonal hindrance and threat to household livelihood, fire is also widely acknowledged as being critical in improving socio-economic and environmental aspects of local livelihoods. Fuelwood resources, which require fire in harvesting in most cases is now scarce, a condition blamed largely on the destructive force frequent of bushfires.

4. Conclusion

This study further demonstrates that fire utilizations among rural households remain important and inseparable from livelihood sustenance. The challenge however remains the inability to effectively regulate its use and prevention. Community and district level fire management techniques have yielded little impact, a situation largely attributed to governance incompatibilities. A pragmatic participatory fire management strategy which engages community, local, regional and national stakeholders is deemed essential urgent.

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A8

Using participatory scenario exploration exercise to examine agricultural land-use/cover change options in semi arid Ghana

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Abstract

In sub-Sahara Africa (SSA), studies on land-use/cover (LUC) change have focused more on change from forest or woodland to other types of LUC. Very few studies have looked at change from one agricultural land-use/cover (ALUC) to another ALUC, and these may have accompanied impact(s) on the environment. Drivers of ALUC identified during household survey (186), interview of stakeholders and information from literature were used to develop descriptive scenarios (what-if-questions) that were presented to farmers during participatory scenario exploration exercise. The drivers used include: [climate (rainfall) and socio-economic (finance availability, fertilizer access, seed prices)]. This study was conducted in northern Ghana, where larger numbers of people derive their livelihood from agriculture. Rainfall related scenarios influence replacement of crop(s) from agricultural land (agricultural-land-conversion); while socio-economic scenarios influence the incorporation of crop(s) to an existing agricultural land (agricultural-land-modification). Farmers may change their ALUC under certain conditions/stressors, and this might have accompanied environmental trade-off. In this part of the world, in-depth, well documented impacts of ALUC on the environment are scanty. Therefore, to effectively direct policy in this direction, it will be necessary to investigate more on the environmental impacts associated with

various agricultural land-use/covers. Furthermore, minimizing the possible associated environmental trade-offs should be of major concern.

Key words: *agricultural land-use/cover, agricultural land-use/cover change drivers, decision making, participatory scenario, semi-arid Ghana.*

A9

Measuring the economic impact of climate change on plantation agriculture in Nigerian: a Ricardian approach

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Abstract

This study used the Ricardian analytical framework to examine the relative importance of climate normals (average long-term temperature and precipitation) in explaining net revenue from Nigerian cocoa plantation farmlands. A survey was carried out for 280 cocoa plantation farmers in seven different cocoa producing regions across Nigeria. The empirical findings suggest high sensitivity of net farm revenue per cocoa hectare to climate normals in Nigeria. On average, reduction in rainfall decreases net farm revenue per plantation hectare whereas warming increases net farm revenue. However, this varies with the three seasons used in the analysis. Furthermore, predictions from uniform climate scenarios and three AOGCM scenarios (i.e., CCC, CCRS and PCM) for the years 2020 and 2060, suggest drastic decline in future net farm revenue between the ranges of -13.4 % to -42.4% depending on the model. This is consistent with previous empirical findings that CC damages could be large in tropical developing countries, depending on the actual climate scenario.

Keywords: *Ricardian analysis, CC, net farm revenue, cocoa plantation, climate simulations, Nigeria.*

JEL Classification: *O13, O21, Q54.*

A10

The effects of climate variability on agricultural productivity in Ghana

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Introduction

Prevailing evidence already shows that in semi-arid regions of Africa, rainfall distribution over the past few years is low and highly variable, spatially and inter-temporally (Amikuzuno and Donkoh, 2012). Growth and development in developing countries (Ghana inclusive) is dependent on agricultural development (World Bank, 2008). This implies that the factors that influence agricultural development, including rainfall and temperature, have relevance to Ghana's development.

Objectives

The objective of the study was to investigate the effects of climate variables on agricultural output in Ghana. We used agricultural data from FAO and climate data from the Ghana Meteorological Service. The period of study was from 1980 to 2011.The variables considered in the models were total agricultural crop value, comprising of 22 major crops in Ghana; land; labour; fertilizer; pesticides; tractor services; livestock; temperature; and rainfall.

Materials and Methods

We adopted Battese and Coelli's (1993, 1995) formulations of the stochastic frontier model which make one-step estimation possible to correct for any inconsistencies. The empirical model adopted a Cobb-Douglas specification. According to Coelli et al. (1998) if the value of crop output, rather than the physical quantities, are used as the dependent variable, then the efficiency scores are economic rather than technical efficiency. The empirical model of the study is as follows:

Table1: Maximum likelihood estimation of the stochastic frontier model

Variable	Coefficient	Standard error	T-value
Crop value			
Constant	1.380	1.201	1.115
Land	-2.795 ***	0.530	-5.268
Labour	2.772 ***	0.197	14.043
Fertilizer	0.005	0.005	1.022
Pesticides	0.055 ***	0.020	2.724
Tractor cost	0.021 ***	0.006	3.856
Livestock value	0.648 **	0.259	2.503
Temperature	-1713.744 ***	0.899	-1906.290
Temperature square	857.431 ***	0.489	1753.762
Rainfall	-973.006 ***	0.895	-1087.433
Rainfall square	486.471 ***	0.449	1082.913
Inefficiency			
Constant	-2.959 **	1.168	-2.534
Temperature	0.118 ***	0.041	2.854
Rainfall	-0.245 ***	0.074	-3.288
Variance parameters			
Sigma squared	0.0186 ***	0.0040	4.7130
Gamma	0.9999 ***	0.0000	26912.3010

*** Significant at 5%; ***Significant at 1%.*

$$Output\ value = \beta_0 + \beta_1 Land + \beta_2 Labour + \beta_3 Fertilizer + \beta_4 Pesticides + \beta_5 Tractor\ \cos t + \beta_6 Livestock + \beta_7 Temperature + \beta_8 Tem\,s\ squared + \beta_8 Ra\inf all + \beta_9 Rain\ squared + u_1$$

$$Inefficiency(u) = \gamma_0 + \gamma_1 Temperature + \gamma_2 Ra\inf all + u_2$$

Results and Discussion

From the Table, the maximum likelihood estimation results of the stochastic frontier model showed that all the variables, except fertilizer, in both the first part and the inefficiency effects model were significant, most of them maintaining their expected signs. However, land had a negative coefficient, implying that more of its use led to decreased output. Also, while the fist terms of temperature and rainfall had negative effects on output; the squared values had positive impacts. This means that at the initial stages of production, low levels of temperature and rainfall led to increased agricultural output, but at the latter stages high levels of these climatic factors led to a continuous rise in output levels. In the inefficiency effects model, however, while temperature had a positive coefficient, the coefficient of rainfall was negative, meaning that high levels of temperature led to inefficiency of farmers, while high levels of rainfall led to increased farmers' efficiency.

Conclusions

The conclusions to be drawn from the findings are that while in the past, relatively low levels of temperature and rainfall were needed to increase agricultural productivity, in recent times and perhaps in future, for output to continue to increase; higher levels of the climatic factors are needed. For farmers to be economically efficient however, temperature levels must reduce while rainfall levels must rise. Thus, while more rainfall is necessary for both growth in agricultural productivity and economic efficiency of farmers, more temperature, though good for agricultural productivity growth, does not augur well for economic efficiency. Since agricultural productivity growth is a means to farmers' economic efficiency, we recommend policies that increase rainfall or its substitute (such as irrigation) but reduce temperature.

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Wednesday 6th August 2014

13:30 – 17:30

ABSTRACTS

SESSION B

B1 » 10

Risk Assessment of Extreme Weather Events

B1

Expert-based assessment of driving forces of land use change and landscape services in the Upper East region, Ghana

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This research focuses at the identification of the most important driving forces of land use change in the Upper East Region, located in northern Ghana, its influence on land use and crop types as well as the consequence for services provided by the landscape, such as crop productivity or freshwater provision.

The analysis is embedded in the WASCAL-initiative (West African Science Service Center on Climate Change and Adapted Land Use) which aims at the improvement of the resilience of sensitive socio-ecological systems (SES) such as the rural area in northern Ghana. WASCAL gives recommendations for adapted land use strategies to the changing environment of the Sudanian Savanna Zone. Experts from scientific institutions in Ghana have been interviewed for the most important driving forces of land use change. Essential landscape services have been identified by the WASCAL-community. The analysis of causal relations between drivers of land use change, its influence on land use types and impact on landscape services will be conducted by means of Bayesian Modeling. Graph theory and probabilistic dependencies are both represented in Bayesian Networks (BN) and give a fast and simplified overview of the complex conditional relations between drivers of land use change, land use types and landscape services. Quantitative as well as qualitative primary and secondary data will be incorporated into the BN. In the case of non-available data or uncertain relations of variables the expert panel will be consulted to fill in missing values and information.

In this presentation, results from the expert consultation and WASCAL-community survey will be presented. The supporting role of the BN within the framework will be highlighted. Finally, it will be shown how the approach could be used for adapted land use planning.

B2

Variation analysis of rainfall and temperature in northern savannahs of Ghana

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Abstract

The study analyses the variation of rainfall and temperature as important climatological parameters which have a great influence on agriculture production in the Northern Savannahs of Ghana. Data for the study is collected from four (4) synoptic meteorological stations of Northern Ghana for the purpose of assessing the level of variation over the various periods. Temperature and rainfall data for over (30) years were analyzed. Among the four (4) stations, inter-annual rainfall was much more variable in the Nyankpala area recording 28.75 % variability compared to the others. Annual rainfall variability was however in the range of 13.65 – 24.14 % for the various periods and locations of the study. The highest temperature was recorded in Navrongo as 42.29 °C whilst the lowest was recorded in the Nyankpala area as 14.27 °C. With these temperature ranges and rainfall amounts, potential evapotranspiration of 181.44 mm was recorded for Tamale whilst Navrongo recorded potential evapotranspiration of 197.56 mm for 48 years as averages. Rainfall and temperature were observed to vary widely and were location dependent and this impacted largely on activities of farmers in the areas in terms of type of crop to plant and timing of planting.

Keywords: *Variation, Temperature, Rainfall, Savannah, Analysis*

Introduction

The rainfall seasons of Ghana are controlled by the movement of the Inter - Tropical Convergence Zone (ITCZ) which oscillates between then northern and southern tropics over the course of every year. A single rainfall regime characterise Northern Ghana and this occurs mainly between May and November, when the ITCZ is in its northern position and the prevailing wind is south - westerly, and a dry season between December and March when the 'Harmattan' wind blows north - easterly.

Rainfall is averagely more than evapotranspiration in Northern Region during the major growing seasons from July-October (Kranjac-Berisavljevic', 1998). If the stresses

of low moisture and high temperature can be alleviated, early planted crops will not only yield more than those planted late but also improve the chance of double cropping by relay or sequential plantings (Ayoade, 1993).

Materials and Methods

The study is done in Northern Ghana considering the Guinea and Sudan Savannah areas. Rainfall and temperature data varying from 29 to 51 years of continuous records were analyzed for Bawku (Manga), Navrongo, Tamale and Nyankpala Synoptic Meteorological Stations. Most records started from the year 1960. Annual rainfall variability was established for each location using the relation developed by Le Houerou and Popov (1981) and presented as equation 1.

V = (59.6 + 0.11P)*100/P..... equation 1
Where;
V = Annual variability (%)
P = Rainfall amount (mm)

The inter-annual variation model developed by McGregor and Nieuwolt (1998) as equation 2 was used to estimate the inter-annual variability of rainfall for the areas.

$$V_r = \frac{\sigma}{p} \times 100 \text{ .....equation 2.}$$

Where:
V_r = inter-annual variability (%)
p = Mean rainfall (mm)
σ = standard deviation of rainfall for the period in consideration.

Results

For the period under consideration the Tamale Synoptic station recorded as its lowest annual rainfall an amount of 695.3 mm in the year 1992 whilst the highest was recorded as 1666.4 mm 1963. An average rainfall of 1093.59 mm was recorded for the 51 years of data with 27 years recording below the average of 1093.59 mm and 24 years recording above the average for the area and the period. Generally annual rainfall amounts below 1000 mm/y was recorded in 15 years whilst 36 years recorded rainfalls above an amount of 1000 mm/y.

Rainfall annual variability ranged from 14.57 – 20.11 % whilst the inter-annual variability of rainfall was realized as 18.35 % for the area.

Forty two (42) years of continuous rainfall in the Nyankpala Synoptic Station was considered during the study and it was observed that the average annual rainfall for the area was 1021.25 mm with the lowest being 453.3 mm recorded in the year 2004 and the highest being 2247.7 mm and recorded in the year 1968. Twenty (20) years were observed to have recorded annual totals below 1000 mm/y whilst twenty two (22) years recorded annual totals above 1000 mm/y. Twenty one (21) years each recorded annual rainfall amounts below and above the average recorded for the period. The records show that rainfall was much more variable in the area compared to the Tamale area with annual variability in the range of 13.65 – 24.14 %. Inter-annual variability was relatively very high (28.75 %).

In the Navrongo Synoptic Station using 53 years of annual rainfall records an annual variability in the range of 15.36 – 19.88 % and inter-annual variability of 15.49 % were recorded. The records show that the lowest amount of rainfall (670.5 mm) was recorded in the year 1977 whilst the highest amount was recorded in the year 1999 as 1365.3 mm. Over the 53 years of rainfall records, an average of 986.92 mm was recorded and largely falling below the averages for Tamale and Nyankpala Synoptic stations. Twenty four (24) years recorded annual totals above the mean rainfall whilst 29 years recorded annual totals below the mean rainfall. Also twenty two (22) years were observed to have recorded annual totals above 1000 mm/y whilst 31 years recorded annual totals below 1000 mm/y or rainfall.

In the Bawku or Manga area which is considered as Sudan Savanna, annual rainfall variations were in the range of 14.81 – 23.93 %. Inter-annual variations were observed as 22.27 % of the rainfall observed for 29 years. Lowest amount was recorded as 460.90 mm and of which occurred in year 1983 whilst the highest was recorded in 2007 as 1562.7 mm. An annual average of 934.4 mm was recorded for the area with 13 years being above the average annual rainfall and 16 years recording annual amounts below the average rainfall. It was observed however that, 8 years of the recorded had recorded rainfall amounts above 1000 mm/y whilst 21 years recorded annual amounts below 1000 mm/y.
Temperature records were observed to vary slightly depending on the location of the synoptic station as presented in **Table 1**.

Table 1: Maximum and Minimum Temperature of Synoptic Stations

Synoptic Station	Maximum Range (°C)	Minimum Range (°C)
Tamale	15.35 – 23.49	22.7 – 34.97
Nyankpala	14.27 – 22.35	21.64 – 34.64
Navrongo	21.85 – 23.7	33.89 – 42.29
Bawku (Manga)	18.41 – 37.79	15.50 – 23.22

With these temperature ranges and rainfall amounts, potential evapotranspiration 181.44 mm was recorded for Tamale whilst Navrongo recorded potential evapotranspiration of 197.56 mm for 48 years as averages.

Discussions

McGregor and Nieuwolt (1998) reported that annual rainfall totals for many tropical regions revealed clear year to year variations of rainfall. Generally variability decreases with increasing rainfall, but there are many exceptions to this rule in the tropics. Usually tropical rains are highly spatially varied as well as temporally variable. Rainfall variability is generally found to be higher in the semi-arid regions than in the humid tropics (Lal, 1987).

Several reports released by researchers on the variability of rainfall have it that the coefficient of variability in Africa to the Southern part of the Sahara is about 22.5 % at 500 mm

and 15 % at 1000 mm annual rainfall (Cochéme and Franquin, 1967). Le Houerou and Popov (1981) reported that, variability increases from 10 – 15 % in the rainforest region to more than 50 % in the desert in tropical Africa.

Temperatures in Northern Ghana are consistently high with small seasonal variations. Average annual temperatures increase from south to north alongside an increase in solar radiation, and a decrease in annual rainfall (Gariba, 2001). High temperatures correlate with high evapotranspiration and direct evaporation. Northern region evapotranspiration as established by Kranjac-Berisavljevic' (1998) is 2,000 mm. This is accompanied with the annual rainfall of about 1,000 – 1,300 mm.

Conclusions

The paper assesses the variability of rainfall in four locations in the Guninea and Sudan Savannah areas of Northern Ghana. Rainfall and temperature were observed to vary widely depending on the location of the station and this impacted largely on activities of farmers in the areas.

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B3

Comparison of GSMaP mvk data with surface data at semi-arid regions in Africa

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Abstract

The semi-arid regions are vulnerable against both flood and draught, but rain-gauge observations are generally sparse and radar observation is fur before implementation in many countries. Thus, the use of satellite derived precipitation data has potential to serve as a mighty tool to detect rather rare precipitation in semi-arid regions which may cause hydrological hazards or bring hydrological benefit. The performance of satellite derived precipitation in semi-arid regions, however, has not yet well examined. According to our preliminary investigation in sub-Saharan sites, the ground measured precipitation is smaller than those retrieved from satellite observation. The underestimation is postulated as that caused by the evaporation of hydro-nuclei before they reach to the ground. Toward the practical use of GSMaP data in sub-Saharan environment we started a comparative study of satellite derived precipitation with ground based observation. The precipitation data from some Ghanaian, Nigerian and Namibian sites are collected and compared with GSMaP data with different spatial and temporal scales and the statistical behavior are examined.

B4

Modeling flood hazard zones at sub-district level with the rational model integrated with GIS and Remote Sensing approaches

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Abstract

Ghana ranks high amongst African countries most exposed to risks from multiple natural hazards. In the Northern Savanna belt, high variability in climate and hydrological flows make the area highly exposed to extreme natural hazards. From 2007 to 2013, there have been consecutive flood events with severe livelihood impacts and food insecurity. This phenomenon is projected to rise under climate change. Robust risk assessment requires accurate flood intensity area mapping to allow for the identification of populations and elements at risk and the retrieval of socio-ecological indicators needed to describe the vulnerability of exposed populations. However, to date no

attempt has been made to delineate the spatial limits of flood prone areas in the Savanna belt at a fine scale. Researchers have relied on global datasets whose resolutions are too course to be relevant for local scale risk assessment whilst disaster managers are using traditional methods such as watermarks on buildings and media reports to identify flood hazard areas. In this study, remote sensing and Geographic Information System (GIS) techniques are combined with a hydrological model to identify and map flood causal factors and subsequently delineate the spatial limits of flood hazard zones at the sub-district level in Bolgatanga and Bongo districts in the Upper East region of Ghana. As a first principle, the approach involves estimating total run-off (discharge) concentrations at different elevations and then determining the relative contributions of each causal factor - land cover, soil type and structure, geology, Digital Elevation Model, precipitation - to historical flood events and then weighting the causal factors before using statistical methods to standardize them. The identified spatial boundaries of different flood intensity classes at 30m resolution will be highly useful for disaster managers to help reduce the risk to flood at the community level where risk outcomes are first materialized.

B5

Validating GSMaP satellite rainfall data with in situ data to facilitate the improvement of algorithms for rainfall estimation using satellite imagery for Ghana

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Abstract
This research attempts to validate rainfall estimates from GSMAP satellite data using in situ observations from the Ghana Meteorological Agency**.** The estimated rainfall from GSMaP is put into various grids and this is used to compare with the estimated GSMaP rainfall to enable the best grid to be chosen and facilitate the algorithm to be appropriately modified so that GSMaP satellite estimated rainfall can be used in any location in Ghana where there is no Meteorological observational network.

Keywords: *GSMap, Algorithms, satellite*

B6

Numerical weather prediction trial: the weather research and forecasting (WRF) model

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Abstract
This paper presents an attempt to use the WRF model as an early warning tool over the CECAR project site. It also seeks to compare our local WRF model output with the GSMaP real time output data using GFS GRIB2 6 hourly forecast dataset as input data. The generated local WRF output data is from three nested domains with the outermost domain being Africa, next West Africa then Ghana respectively. The flooding and drought situation caused by the variable climatic conditions over the study site is what the model seeks to address and analyze in this paper.

B7

Analysis of climate extremes in northern Ghana

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Abstract

This research delves into an analysis of climate extremes in Northern Ghana centering on rainfall, Maximum and Minimum Temperature. It seeks to underscore or validate the IPCC downscaled information on Temperature and Rainfall in the Sudan and Guinea Savannah which lie in the Semi-Arid region of Africa, which is within the scope of the CECAR Africa project.

The World Meteorological- recommended RClimdex under the R software environment is used for this study. The study area includes all the Synoptic areas in Northern Ghana which have daily data spanning a period of more than thirty years.

This analysis will not only help to protects livelihoods but also inform decision makers and planners on diversification in agricultural activities over Northern Ghana.

Keywords: *Climate Extremes, IPCC, Semi-Arid, RClimdex, R Software.*

B8

Development of a Volta-river catchment flood model

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Abstract

This paper presents an attempt to make a large scale Volta river catchment flood model. A distributed rainfall-runoff/flood-inundation (DRR/FI) model is applied for the flood simulation. DRR/FI model simulates the inland water movement with a shallow water equation and the river flow with a St-Venant equation. USGS HydroShed is used for the topography data (elevation, river channel) of the DRR/FI model. The simulated discharge is compared with the Discharge data (daily/monthly discharge) from Global Runoff Data Center (GRDC). Likewise, the simulated inundation is compared with MODIS satellite image. JAXA GSMAP, a satellite rainfall data, as input to DRR/FI is the driving force of the flood propagation. The flood event in 2007 of the catchment is targeted. The paper summarizes these results.

B9

Estimation of the amount of surface runoff contributed from Sissily-Kulpawn catchment within Ghana-Burkina Faso border using Curve Number (CN) method

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Hydrological measurements are essential for the interpretation of water quality, water resource management for irrigation and soil and water conservation structures. Variations in hydrological conditions have important effects on water availability and quality. In rivers, the discharge, velocity of flow, turbulence, depth and water quality is influence by landuse and soil characteristics of the catchment.

The River Sissili, a tributary of the Volta River has a large drainage stretching from Mali, Burkina Faso, Ivory Coast and Benin to Ghana. The River Kulpawn, another tributary of the River Volta, springs in Ghana, near Burkina Faso border and has a smaller catchment area. The two rivers meet around Yagaba in the Mamprugu-Moadugu District. The confluence of these rivers is found in the fertile plain, where extensive cowpea cultivation is carried out on residual moisture. Subsistence rainfed agriculture is the main occupation of the inhabitant in the basin. These agricultural activities normally extended into the river bed, especially in dry years. As a result, the River Kulpawn usually dries-up, forming strings of pools during the dry season.

The secondary data on rainfall of the catchment area of the two river basins is used in the estimation of the runoff from the catchment of these streams, using CN (Curve Number) method. Also available are soil and landuse maps of the catchment which were delineated using with the help of a geographical position system (GPS), to obtain the various extent of the catchment characteristics.

Estimation of the runoff will enable the designing and construction of water harvesting structures that will not only help conserve and maintain soil moisture, but also store water for supplementary irrigation. The contamination of the water from this important tributary of the River Volta will also be reduced.

B10

Rainfall changes in the savannah zone of northern Ghana 1961–2010

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Abstract

This study analyzed the rainfall trends of Northern Ghana to determine any significant changes in rainfall in the last two decade as reported elsewhere in the Savanna zone of West Africa. The objective of the study was to determine any significant changes that may have occurred in the annual rainfall totals post 2000. Agricultural decision making and water resources management in the Savannah Zone depend heavily on rainfall recharges. Rainfall data from Tamale, Yendi, Naworongo and Wa stations for the period 1961-2010 were used for this analysis. Evidence from the long-term rainfall data for the Savanna zone of northern Ghana indicates that rainfall in the last two decades entered into a phase of slight increased compared to the previous two decades. A station by station analysis however indicates that not all station have sustained recovery. Even though the decade of 2001 to 2010 recovered from the 1980 to 2000 period, the post 2000 rainfall has still not reached the levels of the 1960s. Compared to the 1970 and 1980 decades the rainfall situation in the last two decades could be described as an improvement. Hydrological levels may have seen recharges that could be harnessed to support the rain-fed agriculture that is the main stay of the savanna economy. Proper selections of crop varieties could also be useful in improving productivity and improve livelihood.

Thursday 7th August 2014

8:00 – 12:00

ABSTRACTS

SESSION C

C1 » 10

Coping and Adaptation Strategies; Knowledge Innovation

C1

An assessment of rainfall variability under rain fed agriculture: perspectives from local knowledge systems and planning for community resilience in north-western Ghana

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This paper assesses rainfall variability from the perspectives of local people and their local knowledge systems in the context of rain fed agriculture in the Sissala East District, north-western Ghana. Qualitative methods of data collection, specifically, in-depth interviews, focus group discussions and seasonal mapping and analysis were employed for data collection and in- depth analysis of rainfall variability. The results show that rainfall patterns associated with four- main traditional classifications of the stages of the rainfall season have changed over time, at least over three generations and vary significantly between patterns in the past (grandparents era) and present patterns(Children's era). Identifying these seasons, in the local parlance, *as Duonpuso/Chankpaama, Kuduriduon, Vibiiri/Vu Duon and Wawajen/Gbanchan Duon*, the paper observes that rainfall patterns across these four stages in the rainfall season were fairly stable and predictable in the past, dating back to grandparents era, compared with rainfall patterns in contemporary times. Unlike the grandparents' era, rainfall patterns are now characterized by extreme variability, uncertainty, change and unpredictability with dire consequences for rain fed agriculture. The changes in rainfall patterns include variability and uncertainty in the start and end times, delayed onset of the rainy season in most times, reduction in rainfall season and number of rainy days, variability in rainfall distribution and virtual disappearance of some locally classified stages of the rainfall season. To enhance community resilience to rainfall variability, this paper advocates a composite approach to Climate Change Adaptation Planning (CCAP) through District Development Planning (DDP) that emphasizes the localization of local knowledge systems for adaptation within the context of two policy frameworks – decentralization and local governance and the National Climate Change Adaptation Policy Framework.

Keywords: *Rainfall Variability, Agriculture, Local Knowledge, Resilience, Climate Change Adaptation Planning (CCAP).*

C2

Role of agricultural land use and farm management practices for food security and climate change adaptation in semi-arid region of Ghana

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Abstract

In Northern Ghana, demographic changes along with unsustainable agricultural land management practices have affected the ecological integrity of existing agro-ecological systems. Coupled with climate change, farming systems have come under increased pressure. Over the years, farmers have responded to these changes by varying land use and farm management practices. This study examines agricultural land use patterns, changing farm management practices and their implications for food security and climate change adaptation. Farmers (125) across six communities in the Tolon district of Northern Ghana were selected and interviewed face to face on their farms. The survey was conducted at the beginning of farming season and a follow up survey was done during the harvest period. Observations were done through transect walks in both farmlands and the entire landscapes accompanied by key informant interviews with village heads. The results of the study showed that, across the landscapes in all communities, there is hardly any unused land as all lands have been converted into agricultural use except patches of protected groves and formerly abandoned farmlands. A defining feature of agriculture land use is the maintenance of dual farming systems; one close to the compound and far from the compound. While compound farms are mostly planted with maize, the diversity of cropping patterns and management practices in bush farms are highly variable and complex, and these depend on the crop type and

resources available to the farmer. The most predominant farm management practice observed were chemical fertilizer use, pesticides, manure application, ploughing, insitu weed turning and mixed cropping; and crop rotation. On the other hand, residue retention, mulch, compost and fallow were the least farm management practice observed. Increasing frequency of droughts periods, low input addition particularly chemical fertilizer, abandoning of farmlands due to nutrients exhaustion and high youth migration are the main constraint to farm productivity and crop yield. Farmer's adaptation response to drought induced climate change is low and this may affect food security in the regions. Stakeholder intervention options particularly in soil management and use of improved crop varieties is recommended. There are opportunities to adapt cost effective and locally appropriate soil and water conservation properties tried and tested elsewhere in semi-arid parts of West Africa.

C3

Community boundary and asset mapping: strategy for effective resource management in context of climate change adaptation

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Abstract

Overdependence on direct and indirect ecological services for food and income continue to grow in most rural communities across the globe. In Northern Ghana, a predominantly rural region, communities use and maintain important ecological landscapes vital for supporting livelihoods, food and income. However, these resources are often shared and therefore cut across different communities whose boundaries may be indeterminate. Hence, in such communities with a history of intertribal conflicts over land and other natural resources, it is important that not only is there a clear cut understanding of the stock of existing ecological resources within specific communities but also resources that may be shared. This has become particularly important as climate change along with demographic changes present a major challenge to the management and utilization of already stressed ecological services. Using drought prone agricultural dependent communities in the Tolon District of Northern Ghana as case study, the study seeks to identify and map key socio-ecological resources owned and shared by communities as well as the governance pertaining to the management of these resources including how conflicts over shared resources are resolved. Data utilized were mainly in the form of rural participatory approaches such as group transect walks, focus group discussions, and key informant interviews. In addition key informant asset mapping aided the use of GPS for tracking and mapping community assets and boundary in GIS interphase. The results show that, across the communities, the key shared resources identified included dams or water systems, land, trees (mostly economic trees), and forest/groves. Incidence of previous conflicts was reported over access to shared economic trees such as dawadawa and Shea, farmlands including river valleys. Unless a resource provided by an external agency where village committees are formed to manage such resources, the management of locally owned and shared resources are under the control of traditional heads through enforcement of taboos, practices and conventions. Also, while informants generally indicated they knew the boundaries of their communities through the use of important land marks or resources, they recognized the limits and unreliability of these methods and therefore affirmed their support for formalization of these boundaries through proper documentation. By comparing the individual community boundary delineation, the community boundary maps showed overlaps between lands claimed by different communities. The study concludes that, the continued use of traditional boundary delineation could be a source of future conflicts over stressed resources particularly in an era of climate change. There is therefore the need for the formalization of the ownership and status of intercommunity boundary and shared resources respectively. This is essential for future resource management and to enable external agencies or stakeholders plan especially in times of disaster management.

C4

Vulnerability of settled Fulani pastoralists to climate change and emerging innovations for adaptation in southwest Nigeria

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Abstract
Settled Fulani pastoralists contribute significantly to local and national food security in Nigeria and the West African region. However, their livelihood is constrained by inadequate forage pasture and water, exacerbated by climate change. This study identified important climatic factors to pastoralists and their variability; assessed vulnerability to climate change and examined emerging innovations for livelihoods adaptation among settled agro-pastoralists in Ogun and Oyo States, Nigeria. Personalised interviews and focus group discussions were conducted for household level data collection. Vulnerability, as a funtion of exposure, sensitivity and resilience was scaled on a 3-point rating scale of 'not vulnerable, vunerable and highly vulnerable'. Time-series NDVI data were analyzed for annual, seasonal, and decadal averages and anomalies. Vulnerability index ranged from 0.45-0.9; majority (57.7%) fell in the 'vulnerable' category. The mean monthly rainfall has been increasing by 6.5mm/month/decade from 1982 to 2010. The temperature has been rising at about 0.4°C/month/decade. For most of the years up to 2001, both average rainfall and temperature are below normal by between 1∂ and 2∂. The standard rainfall anomalies also show that rainfall is not fairly distributed across the seasons. The average seasonal NDVI from 1982-2009 shows that for four seasons was not significantly different. The highest seasonal correlations obtained between NDVI and precipitation and temperature in the Dec-Jan-Feb of the decades 2000s, are 0.355 and -0.323 for rainfall and temperature respectively. While rising and fairly distributed rainfall is preferred, increased warming implies more evaporation and evapo-transpiration with no substantial positive effect on the growth of forests and woodlands. Therefore, additional water need created by higher temperatures were not be met by the increase in rainfall, implying pastoralists' vulnerability to climate variability. Coordinated efforts at increasing pastoralists' adaptive capacity and building long-term mitigations will reduce climate impact on pastoral livelihoods in the region.

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C5

Estimating surface water runoff using Curve Number (CN) method and its effect on crop cultivation in the Bontanse basin

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The River Bontanse, a perennial stream drains communities in Tolon and Kumbungu Districts in Northern Ghana which include Voggu, Dalun, Kumbungu, Wuba and Kpalisogu. The basin covers about 2085 sq km and is located in a drought prone area of very unreliable rainfall pattern. Annual dry spells during the raining season is very common which results in annual crop failure in most farmers' fields.

River Bontanse, however, takes of its source from Tolon highlands and drains down to Bontanga where, it is dammed for irrigation at the Bontanga Irrigation Project (BIP).

BIP has a potential of 800ha of irrigable area, of which only 434ha is currently developed and under cultivation. The major crop cultivated both in dry and raining season at BIP is rice. The World Bank recently sponsored the rehabilitation of irrigation infrastructure at BIP under the Millennium Challenge Compact (MCC), a programme designed to help reduce rural poverty in Ghana through targeted agriculture. The Bontanga reservoir also serves as a source of livelihood for migrant fishermen.

The inhabitants cultivate cereal crops in the BIP watershed; they are mostly subsistence farmers who depend on family lands. Fragmentation of these farm lands has resulted in an average household of 7 people possessing only 2.5 acres of land (1ha). Increase in landuse (mainly homesteads and poor tillage practices) in the basin has partially silted Bontanse and has affected the supply of water from surface runoff to the river, dugouts, wells, small scale dams in the study area as well as the dam reservoir at BIP. The increased number of dugouts and small scale dams in the catchment serve as sinks which also affects the reservoir of BIP negatively, especially in dry years.

The over 45years rainfall and other climatic data are available for computing estimates of runoff. Soil and landuse maps with topographical sheets were used to delineate the basin with the help of a geographical position system (GPS). The areal extent of the various catchment characteristics was obtained. These parameters are relevant in the estimation of surface runoff using curve number (CN) method.

Estimation of the runoff will enable the designing and construction of soil and water conservation structures to help reduce the effect of rainfall variability on crop production in the basin. The study will also help to introduce measures to reduce contamination and siltation of the water in the reservoir.

C6

Micro-level farmers' adaptation strategies to climate change in the semi-arid tropics in Tolon district, Ghana

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Abstract

Climate change is a big challenge to the agricultural sector of semi-arid tropical regions, especially for those who depend on this sector directly and indirectly. Agriculture in most sub-Saharan African countries, including Ghana is rain fed, and this makes it even more susceptible to climate variations. Therefore, the farmers are enforced to adopt the necessary adaptation measures in order to subsist. In this paper, we have examined the farmers' adaptation strategies to mitigate the effect of climate change, perceptions of the causes of climate change, and the factors that influenced the adoption measures. A cross sectional household survey was conducted in six different communities: Cheshegu, Daboshie, Fihini, Kpalgun, Zagua, Yoggu in Tolon district in August 2013 with a sample of 150 compound houses. Both qualitative and quantitative methods, including the estimation of a multinomial probit model, were employed in analyzing the data. In the view of the farmers religious (e.g. anger on the part of the gods and ancestors) and environmental factors (e.g. deforestation) were the main causes of climate change. The major adaptation measures also included the adoption of drought resistant crop varieties, organic and inorganic fertilizer application, improved cropping techniques and agriculture and climate-related extension services. The main factors that influenced the adoption of the measures were level of education, age of the farmer, inputs accessibility and communication. The key policy implications should include making drought resistant varieties and fertilizers more affordable and increasing access to extension services as well as weather/climate information.

Keywords: *adaptation strategies, perceptions, climate change, probit model, Ghana*

C7

Ecosystem services assessment using a stakeholder-based approach: cases of Bolgatanga and Bongo districts in the Upper East region, Ghana

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Abstract

The evaluation of the ecosystem services becomes a means of providing an integrated perspective to gauge the effects of land use in a certain environmental condition. The Northern region of Ghana confronted with unfavorable climate conditions and socio-economic situations experiences a wide range of land use changes that affect directly and indirectly the ecosystem services. Thus, identifying the states of the ecosystem services helps to diagnose the agricultural land uses in this region. This research aims to suggest a stakeholder-based assessment framework for estimating the potential capacity of land use to provide the ecosystem services in Bolgatanga and Bongo districts of the Upper East Region in Ghana. The agricultural extension officers generally called as field officers are the stakeholders in this research, who are charged in offering technical advice and introducing new technologies to farmers while monitoring and reporting the performances of the farming systems. Using a participatory process with the field officers, the types of the ecosystem services to interpret the regionally specific effects of farming and the impacts of the land use types on the ecosystem services are determined. The different values of the land use types on the ecosystem services are elaborated between 0 and 100 through standardization. Then,

the GISCAME platform is used to visualize the impacts of the different land use types on the provision of the ecosystem services, which shows higher or lower states of them based on the current land use patterns. The results of this research can provide a framework to understand the responses of ecosystems to human activities such as agricultural land use practices and support decision making processes of the stakeholders in order to maintain or improve the ecosystem services.

C8

Farmer innovation and household resilience to climate shocks: insights from north-east Ghana

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Introduction

North-east Ghana is characterized by frequent droughts and floods which adversely affect farming, the primary source of livelihood for majority of the households in the region. Given the rapidly changing climate, these adverse shocks are expected to become more pervasive. Resilience building is, therefore, necessary for farm households to be able to withstand any future climatic shocks. Over the years, there has been increased development and diffusion of technological innovations to farmers, and there are several projects and policy interventions facilitating the adoption of these introduced innovations. With the rapidly changing economic environments, however, local farmers do not only adopt but also generate innovations (Sanginga et al. 2008; Conway and Wilson 2012). They engage in informal experimentation, develop new technologies and modify or adapt external innovations to suit their local environments, and these practices (which are commonly referred to as farmer innovation) are claimed to play an important role in building their resilience to changing environments and addressing food insecurity challenges (Rej and Waters-Bayer 2001; Kummer et al. 2012). The aim of this paper is to assess the contribution of farmer innovation in building household resilience to climate shocks.

Methods

In measuring resilience to climate shocks, we adapted the resilience tool proposed by FAO (2010). This tool was originally designed to measure resilience to food insecurity, but it can serve as a useful framework for analysing households' capacity to absorb negative unpredictable shocks and stresses such as climate change. The advantage of this tool is that it considers short term actions that help households to cope in case of shocks but also long term actions which contribute to resilience building over time FAO (2010). The resilience tool consists of six components: income and food access, access to basic services, safety nets, assets, adaptive capacity and stability. Each of the six components has a specific set of indicators which can confer resilience. Household-level data on these indicators were obtained from the field survey. Two indices were then developed from these indicators using equal and unequal weighting approaches. We expect farmer innovation to contribute to household resilience mainly through the income and food access, assets, adaptive capacity, and stability components.

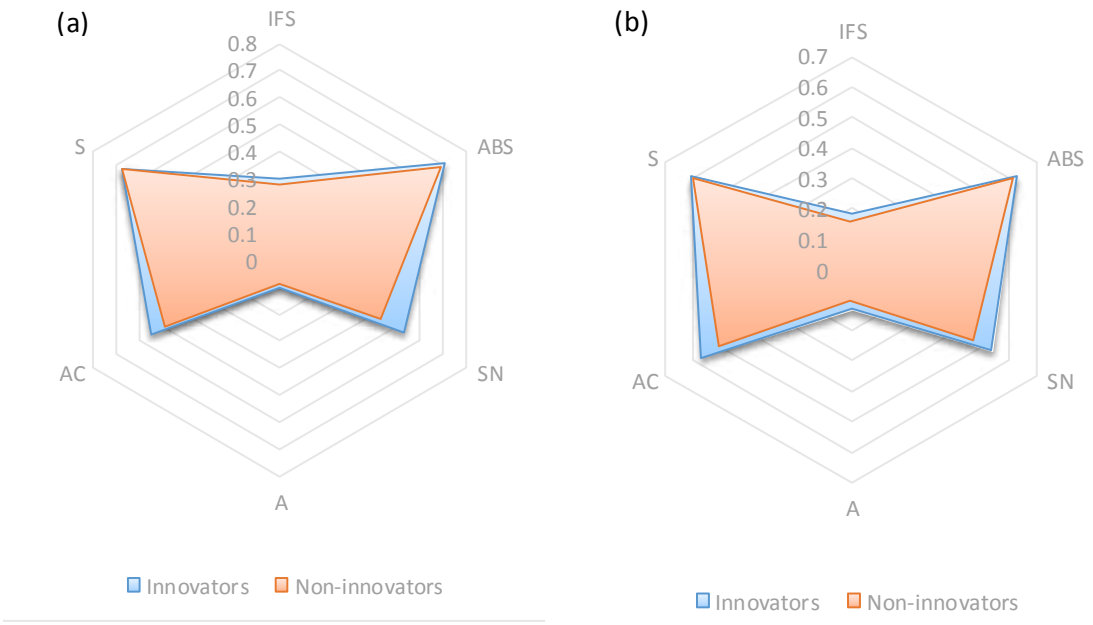
To estimate the effect of farmer innovation on household resilience to climate shocks, we use the endogenous switching regression (ESR) technique which account for potential non-random selection bias of innovation decision. The coefficients from the ESR model was used to derive the expected values of household resilience scores, which were then used in estimating the average treatment effect on the treated (ATT) and the average treatment effect on the untreated (ATU). The ATT compares the resilience score of innovators with and without innovation while the ATU compares the resilience score of the non-innovators with and without innovation.

The empirical analysis is based on data for the 2011-2012 agricultural season obtained from a household survey conducted in Bongo, Kassena Nankana East (KNE) and Kassena Nankana West (KNW) districts in the Upper East Region of Ghana. Overall, our sample consists of 409 farm households randomly selected from the three districts.

Results

The results of the major components of the resilience framework using equal and unequal weighting of indicators approach are presented in **Figures 1a** and **1b**, respectively. The two figures show that the component score for innovators and non-innovators are almost similar irrespective of the weighting method employed. Innovators and non-innovators have identical scores in terms of access to basic services and stability but differ marginally with respect to safety nets and adaptive capacity. The figures also indicate that households in the study region are moderately resilient in terms of access to basic services, safety nets, adaptive capacity and stability but weakly resilient with respect to income and food access, and assets.

We show that the drivers of household resilience to climate shocks are relatively similar, irrespective of the weighting approach employed. Similar to Alinovi et al. (2010), we found that male-headed households are more resilient than female headed-households, but the coefficients are only significant for non-innovators. Dependency ratio and labour shock are negatively associated with resilience in both innovation groups. In contrast, wealth and access- related variables such as value of household assets, livestock and land holdings, credit access,



Note: IFS=Income and Food Access; ABS=Access to Basic Services; SN=Safety Net; A=Assets; AC=Adaptive Capacity; S=Stability

Figure 1: Resilience by innovation groups using: (a) equal weights (b) unequal weights of indicators

and group membership are positively linked with resilience in both groups. Education also positively and significantly influences resilience, but it is only significant for innovators. The results also show that climate shocks increase significantly with resilience. Thus, the more households experience shocks, the more resilience they become. This may suggest that households learn from past experiences and build capacities to adapt to future shocks. We also found that that households located in KNE and KNW districts are more resilient to climate shocks than those in Bongo district.

The treatment effect results indicate that farmer innovation significantly enhances innovative households' resilience to climate shocks. Using equal weighting of resilience indicators' approach, we find that farmer innovation improves innovative households' resilience to climate shock by 47 percent. Similarly, the result of the ATT using unequal weighting approach implies that innovative households are about 12 percent more resilient to climate shock than they would have been if they were not to innovate. The large difference between the two ATT's seems to suggest that the equal weighting method of generating the resilience score leads to over-estimation of the resilience effects of farmer innovation. Finally, the ATU results indicate that the non-innovators decision not to innovate appear to be rational as they would have been about 2-3 percent worse off in terms of resilience to climate shocks if they were to innovate.

Conclusion

We show in this paper that farm households go beyond adoption of externally-driven technologies to generate innovations, and these innovations contribute significantly and positively to enhancing households' resilience to climate shocks in the study region. Thus, our results strengthen arguments for better support for farmer innovation as a complement to externally promoted technologies.

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C9

Towards climate change adaptation modeling: lessons from farmer responses to environmental changes in Ghana

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Abstract

Climate change appears to be a reality. Adaptation to it is a critical issue because of the serious implications of climate changes for livelihoods and the sustainability of human futures the world-over. A possible approach to this issue, which this paper explores with reference to Ghana, is to extrapolate from empirical studies of actual local farmer responses to agro-environmental changes such as land degradation and climate variability, for the purpose of long-term climate change adaptive modeling. Concepts of risk, action-response, resilience, vulnerability and adaptive capacity feature centrally in the theoretical framework for the steps towards the modeling of adaptation to climate change.

To measure indigenous farmer responses to climate-agro-environmental changes, survey data collected from traditional farmers were analyzed to answer the related research questions: (i) to what extent do farmers understand and respond to/support adaptation and mitigation actions, and (ii) do beliefs and concerns about climate change influence those attitudes (iii) What are the specific responses of famers to climate change adaptation. Results indicated diverse opinion on climate change; however, a greater percentage of farmers who were concerned about the impacts of climate change on agriculture and attributed it to human-induced activities had more positive attitudes toward both adaptive and mitigative management strategies.

Resilience assessment through careful ecosystem and livelihoods evaluation was carried out to identify key indicators that best define factors that determine farmers' adaptation capacity to climate change. Livelihood assets were noted to be of an influential and determining factor in farmers' response to climate change adaptation. It was observed that farmers response to environmental changes cut across soil and water conservation, tree planting and traditional method of farming (*proka*); these are seen as critical not only by way of improving upon fertility of soils, which has been the leading cause of decline in agricultural productivity and deterioration factor of living conditions, but also managing agricultural lands sustainably.

The study recommends the need to strengthen farmers' capacities to plan and implement climate adaptation programmes through community-based modeling.

Keywords: *climate change, farmer response, livelihoods, sustainability, adaptive modeling*

C10

Use of organic waste in urban horticulture - innovations and opportunities to increase agricultural resilience in Tamale metropolis, Ghana

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Introduction

Tamale Metropolis is the largest urban centre in Northern Ghana, enjoying rapid population growth (26% increase within the past 10 years), which also results in large waste generation. Some methods of re-using urban waste by local smallholder farmers and urban unemployed youth include application of faecal sludge to peri-urban farms and applying waste water from open drains to vegetable crops. These products are sold on city's local markets and health concerns related to both producers and consumers have generated a lot of attention among different stakeholders.

Practices of waste recycling and use in farming, as applied in Tamale, come as a result of challenges faced by urban and peri-urban famers in an adverse environment. Wisner et al (2004), for example, reports that the vulnerability of agriculture is not determined by the nature and magnitude of environmental stress like climate change *per se*, but by the societal capacity to cope with and/or recover from environmental change. This view is important in order to understand issues related to vulnerability of the urban and peri-urban farmers within Tamale.

Study Area Description

Tamale Metropolis is poorly endowed with water bodies. The only natural water systems are streams, flowing only during the rainy season. Aside this, some artificial dams and dug-outs

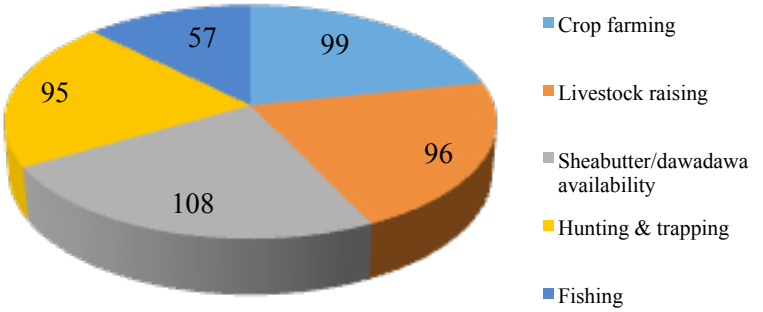

Figure 1. Livelihood activities most vulnerable to climate change (n=110, multiple responses) (Source: START Project household survey, 2012)

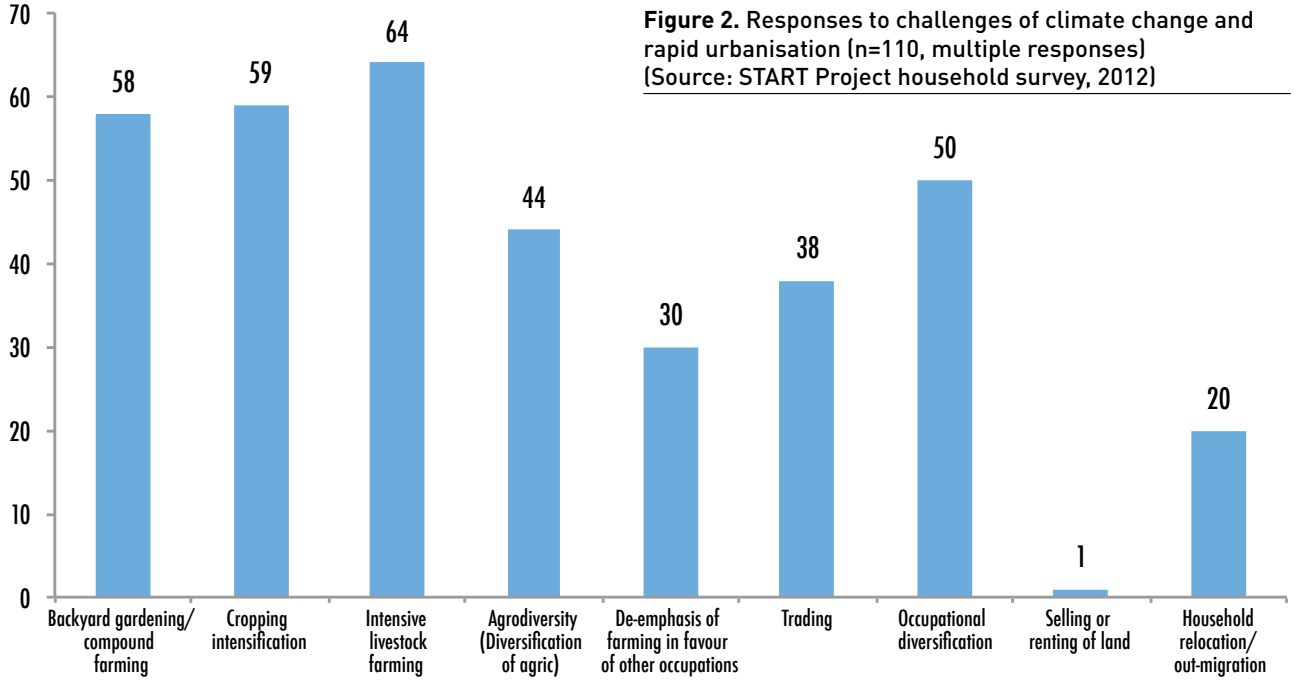

Figure 2. Responses to challenges of climate change and rapid urbanisation (n=110, multiple responses) (Source: START Project household survey, 2012)

have been created. Two of such dams are notably, Builpela and Lamashegu dams. There are about 91 dug-outs in total, dotted around communities within the Metropolis. Where dug-outs have been provided, they serve as watering points for animals, as well as for domestic purposes. Many the dug-outs cannot be used during the dry season, due to high evaporation rates and both people and animals have to travel long distances searching for water (http://ghanadistricts.com/districts/).

Urban and peri-urban farmers rely on rainfall for food production during the rainy season, and compete for other water resources, such as dams, wells and wastewater from drains during the dry season. Despite difficult conditions and limited water availability, these farmers contribute significantly to the food and nutritional requirements of the urban population.

Risks involved in urban and peri-urban farming in Tamale

Significant farming activities in close proximity to rapid and partly un-planned urban developments, alongside general lack of joint planning between institutions responsible for urban water treatments are characterising Tamale Metropolis. These problems are acerbated by erratic rainfall and rising temperatures, as well as other unfavorable climatic conditions, such as flush floods.

Uncertain climatic situation result in rainfall, which is increasingly unreliable, and water in wells and dams and dug-outs is reduced in quantity during dry season, due to higher evaporation losses related to increased temperatures. These climatic factors result in corresponding deterioration of urban and peri-urban agriculture. Farmers try to adapt to these conditions by diversification and other response methods to reduce vulnerability of the framing practices.

Substantial risks involved in the urban farming activities in Tamale, with obvious links drawn between cultivation of rice for example, and increase in malaria incidence, or links between wastewater vegetable irrigation and various communicable diseases.

Reasons for urban farming

University for Development Studies, a main institution of higher learning in the study area, has collaborated with many organisations to improve existing conditions experienced by small scale farmers, including partners such as CECAR Africa Project, local NGOs (DeCo!), international research institutions (IWMI), WASH Alliance, RUAF (The Netherlands) and UrbanFood^{Plus} Project (Germany-W. Africa).

Surveys of urban farming carried out in Tamale during START Project (2011/12), as well as other research initiatives (WHO, 2006, IWMI/KNUST, 2011, etc.) show the following results:

Figure 1 clearly shows that traditional activities typical for the farming systems in Tamale area are in decline. Gathering products from the wild (ex. dawadawa collection and processing) and hunting are directly affected by rapid urbanisation, as well as climate changes.

Due to the shortage of land, crop farming as well as extensive livestock rearing are also affected by these changes.

However, some opportunities for improvement under the changing conditions are reckognized by the urban and peri-urban farmers in Tamale. Farmers see opportunities for cultivation of more resilient crops and rearing livestock as possibility to reduce vulnerability of their situation. They also see present situation as motivation for agricultural diversification and intensive agriculture.

Some innovations are also tested currently for wider use. These include: use of urine for vegetable cultivation, co-composting of faecal sludge with other organic waste into safer products, training programmes for urban farmers in handling compost made from organic waste and introduction of business models for small-scale entrepreneurs engaged in collection and processing of waste.

Conclusions

- Rapid urbanisation and climatic risks directly impact livelihood of urban and peri-urban farmers in Tamale
- Increasing incidence of drought and floods are symptoms of the climate risks.
- Urbanisation is adversely affecting traditional livelihood forms, foremostly by destabilising land holding arrangements, especially of poor and other vulnerable groups
- A number of benefits for enhancing livelihoods, food production and security are associated with urbanisation through opportunities for land use intensification, waste recycling and multiple use of water resources

Recommendations

Urban policy, planning and governance should be modified to address more both the positive and negative aspects of urbanisation and climate conditions and to increase both popular resiliency and adaptive capacity of smallholder farmers.

Acknowledgements

Grateful acknowledgements are due to all participants in the 2011/12 START household survey in Tamale, notably, Prof. E.A. Gyasi, Dr. F. Obeng and Mr. I. Fuseini.

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Thursday 7th August 2014

8:00 – 12:00

ABSTRACTS

SESSION D

D1 » 10

Natural Resource Management and Interventions

D1

(Presentation Cancelled)

Transnational climate change resilience strategies for the sustainable landscape management in the Blue Nile river basins: linking climate knowledge from semi-arid of East Africa

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Abstract

The Blue Nile River is an important shared resource of semi-arid countries in Ethiopia, Sudan and Egypt of East Africa, which is the major contributor of water to the main Nile River. To drive economic development, the Ethiopian government plans to utilize Nile water resources for both irrigation and hydropower. There is great uncertainty about the impacts of climate change in the basin and there have been few systematic studies of the possible implications for water resource development. Major natural hazards such as flood, drought, sand storms and other calamities that inflict loss of lives and costly damage to property are always a threat in the Nile River Basins, and covering major other areas in Sudan and other adjoining areas. Situated in the tropics, its climate ranges from arid in the north to tropical wet-and-dry in the far southwest. Moreover, the Nile Basin areas inevitably suffer from climate-related calamities similar to those experienced recently. With continued development in the lowlands and urban areas, and growing populations, it is expected that damage to infrastructure and human losses would persist and even rise unless appropriate measures are immediately implemented by concerned agencies.

Coupled processes of low investment capacity and land degradation currently drive a cycle of depressed agricultural yields and persistent poverty through much of the Ethiopian Highlands, including the Blue Nile (Abay River) headwaters (BNH) region and downstream areas of Sudan to link climate knowledge from both countries toward food, water and energy security. This cycle is reinforced by the dramatic interannual climate variability observed in the transnational level. There is reason for concern that conditions will deteriorate in coming decades, given a changing climate that may bring more frequent drought and more intense precipitation events to the region. At the same time, land use pressures are expected to increase due to rapid population growth across the BNRB. However, the same coupling of natural and human systems that currently reinforces poverty in this region also offers opportunity. Vulnerability to climate change is a function of adaptive capacity in the face of exposure to stress combined with physical and social sensitivity to exposure. Recognizing this relationship, we propose to examine how climate variability has impacted agroecosystems of the BNRB over the past 50 years, to project the risk of climate change impacts over the next 50 years, and to evaluate how information on projected risk influences adaptation decisions across diverse communities in both countries. Currently, climate variability reinforces the link between inadequate investment and degradation and between degradation and low yields. Low capacity within the region and inadequate access to external capital reinforce the links between low yields, poverty, and weak investment in agriculture and large-scale water resources development for irrigation and hydropower energy. Climate change threatens to accelerate this cycle, while ecosystem-based adaptation strategies offer an opportunity to slow and to reverse it. To provide one relatively simple example of how the proposed coupling might operate, consider the following scenario: climate change leads to an increase in intense precipitation events and a rise in growing season temperatures. For agricultural communities, the importance of these changes in climate will depend on levels of exposure (local climate change patterns), sensitivity (impacts of change on crops, soils, and large-scale water infrastructure) and adaptive capacity (wealth, access to markets, risk aversion, food-water-energy nexus security) that, together, determine the distribution of vulnerability across the BNRB: (Vulnerability = (adaptive capacity) – (sensitivity + exposure)). With respect to degradation, an increase in intense precipitation events might lead to increased erosion for traditional cultivation practices that rely on intensive tillage. Increased rates of erosion would depress crop yields and also increase sediment flux into the Blue Nile. Reduced yields would amplify pressure to expand cultivation into remaining forested zones and to intensify cultivation on existing agricultural lands, which could lead to further land degradation. Increased sediment flux, meanwhile, would have a detrimental impact on downstream users (Sudan) of the Blue Nile. Timely identification of adaptive cropping strategies and soil management options, in combination with vulnerability-reducing investments in large-scale water irrigation and hydropower, as well as forestation and diversified income streams, can plausibly counteract and even reverse these impacts, provided that communities and outside development actors have access to credible projections of relevant climate risks on an adequate planning horizon. This paper presents some initial research conducted to determine the impact of climate change scenarios using CMIP5 on the performance of existing and planned irrigation and hydropower schemes in Ethiopia and the implications for flows into Sudan.

D2

Women-farmers' perceptions and adaptations to climate change and variability in the transitional zone of Ghana: the case of Atuahenekrom in Sunyani Municipality

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Abstract

Climate change and variability effects though location specific and disproportionately distributed have overall global impact on food security, agricultural development, health, environmental sustainability and the general wellbeing of man-kind. In Africa specifically Ghana, the impact of climate are being observed in increases in atmospheric temperature, changes in rainfall patterns, occurrences of flood and rise in sea level etc. Invariably the impact of climate change and variability on women tend to be different from that of men because the concerns and needs of women are different from that of men. Many studies revealed that variations in the effects of these fluctuations may have gender disparities and women are identified to be severely affected by climate change compared to men as many women are engaged in agriculture than men. Further, socio-cultural and structural challenges limit their access to productive resources/ opportunities for sustainable agriculture. The study was conducted to assess the perception of women farmers on climate change on their agricultural activities, the local adaptation strategies women farmers use to cope with climate change and variability in the Atuahenekrom, in the Sunyani Municipality of Brong-Ahafo part of the Forest-savanna transitional zone of Ghana. It examined women farmers' understanding of climate variability and changes**,** their perceptions of the change on agricultural activities, livelihoods and experiences as well as local strategies in coping with these changes. Primary and Secondary data were collected using questionnaires, interviews and literature materials. Data obtained from the quantitative were analyzed using SPSS to establish distributions and relations existing between measured variables, and the qualitative part were grouped under thematic areas, coded with quotations and expressions cited to support the quantitative analysis. The results obtained indicated women farmers' perception of climate change was mainly linked to changes in temperature, rainfall, wind and drought activities. Many of them attributed these changes to the degradation of forest cover. The option of changing crop varieties, alternative livelihood activities (for example: off-farm, on-farm activities) and the use of agrochemicals were some of the adaptive measure undertaken by some of these farmers. Majority of them attested to the increase in atmospheric temperature, the reduction in rainfall amount and intensities over the past decades. They further admitted the lack of income and financial challenges to be the driving forces for their dependency on rain-fed agriculture.

Keywords: *Women-Farmers' Perceptions, Adaptations, Climate Change and Variability, Transitional Zone of Ghana*

D3

Green farming practice for climate change mitigation and adaptation: experience with usual practice and vetiver technology

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Introduction

Steep lands are not suitable for cultivation because it is difficult to retain soil on it once the natural vegetation is cleared (Oku *et al*, 2011). Despite this, a large extent of cultivated area in southeastern Nigeria has moderate to steep land. The cultivation of steep land will not only continue, but will expand even in the future, according to Juo and Thurow (1998). The challenge begins when a forest or vegetation covering steep land is cleared and the slope is converted to farmland. The natural forest functions and services are lost (Faust, 2014); degradation process begins as the natural equilibrium is disturbed. Soil, water, carbon, nitrogen and other plant nutrient fluxes flows out of the system and are harvested off

the farmers' field through erosion (Oku and Aiyelari, 2014). During erosion, carbon in the form of carbon dioxide and nitrogen as nitrous dioxide escapes from the soil and adds to atmospheric greenhouse gases (GHGs). Uncontrolled erosion erodes soil resilience to deal with climate and water crises and leaves behind exhausted soil with low productivity and fertility and poor harvest. With climate change rainfall is either low, inadequate with short dry spells within growing season or very erosive washing away plants, soil and nutrients from farmers' fields. Climate change impact has manifested in poor crop yield and harvest, low farmers' income and poverty. As climate change intensifies, steep land farmers' challenges will also increase. Reports from localities where steep land cultivation is common in (developing countries) show that the soil is getting "thinner", stony and "tired" (Hellin, 2003) and yields are continuously declining. Yet farmers are not convinced that their crop yields and farming practices can be resilient to the impact of climate change, if they adopt smart and green farming practice. An adoptable and diffusible soil and water conservation technology needs to be smart and green, easy to instruct resource poor farmers; with low implementation and maintenance cost. Smart technology will increase productivity and farmers' income, enhanced resilience of livelihood, reduce and remove greenhouse emissions from the atmosphere (FAO, nd). From on-farm studies the characteristics of smart agriculture technology and more beneficial attributes were found in Vetiver Technology (VT). The objective of this paper is to share field experience when VT was compared with Usual Practice (UP) in Southeastern Nigeria.

Material and methods

The on-farm study was conducted on a farmer's field located on a 55 % slope in the southeastern region of Nigeria. (5º 45 - 6º 30 N; 8º 00 - 9º 30 E). The rainy season here starts from April, while the dry season commences from October each year. The rainfall pattern is bi- modal with peaks in June and September. The annual rainfall of the area recorded over a fifty year period ranged from 2000 to 2250 mm (CRADP, 1992). The field plots were erosion plots with vetiver buffer strips {Vetiver Technology (VT)}. Erosion plots are devices for measuring runoff and soil loss from agricultural land (Biswas and Mukherjee, 2005). Each erosion plot was 150 m^2 (Hudson, 1993) measured 50 m long and 3 m wide. Vetiver were planted along the contour at different surface interval spacing; 5, 15, 25 m and fields without VT known as Usual practice {(FP) (control)}. All traditional farming practices such as pre-planting, planting and post-planting activities were done within this space. Maize and cassava (mixture) were planted on mounds as practiced in the study area. Measurements were taken for maize grain and fresh cassava tuber yields. Daily rainfall at the project site was taken. Water or rainfall and soil losses were collected in the morning after previous day's rain (Hudson, 1993). Amount (mm) of water loss was estimated by dividing the volume by the area of the farmer's field that generated the water (Hudson, 1993). Data from water and soil, carbon and nitrogen losses were determined using standard laboratory methods. The data and crop yields were subjected to analysis of variance and mean separated using Duncan Multiple Range Test (DMRT) at $P<0.05$ level of significance.

Results

Table 1. Water loss on farmers' field under Usual Practice and Vetiver Technology.

Technologies	Rainfall loss in 2010 (Total rainfall = 1200 mm)		Rainfall loss in 2011 (Total rainfall = 711 mm)	
	(%)	(mm)	(%)	(mm)
Usual Practice	29	347	21	150
5	7	85	8	58
15	12	147	11	76
15	13	152	11	80

5, 15 and 25 m = vetiver buffer surface intervals

Table 2. Carbon and nitrous oxide loss in eroded sediment under Usual Practice and Vetiver Technology

Technologies	Carbon loss (kg ha^{-1} yr^{-1})		Nitrous oxide loss (kg ha^{-1} yr^{-1})	
	2010	2011	2010	2011
Usual Practice	70a	90a	7a	9a
5m	32c	18d	3c	2b
15m	48b	29c	5b	3b
25m	45b	47b	5b	3b

5, 15 and 25 m = vetiver buffer surface intervals

Table 4. Maize and fresh cassava tuber yields under Usual Practice and Vetiver Technology

Technologies	Maize yield (t ha^{-1})		Cassava fresh tuber yield (t ha^{-1})	
	2010	2011	2010	2011
Usual Practice	1.3c	1.18c	92c	51d
5	2.02a	2.23a	162a	199a
15	1.67b	1.99b	135b	158b
15	1.74b	1.98b	130b	138c

5, 15 and 25 m = vetiver buffer surface intervals

Discussion

Rainfall in 2010 and 2011 was 50 - 68 % below the annual rainfall recorded for the area decades back (CRADP, 1992). The declining trend in annual rainfall could be attributed to massive deforestation in the area and global climate change impact. Vetiver Technology (VT) allows the farmer derives maximum benefit from every millimetre of rain that drop on the field by significantly enhanced water infiltration and reducing water loss from the field through erosion. Under VT only 7-8 % of rainfall was loss on the farmers' field, whereas, 21 -29 % of total rainfall was loss under Usual Practice (UP).

This was more effective with vetiver buffer strip installed at 5 m surface intervals. The 5 m spacing increased water infiltration, conserved and improved water economy within the plant rooting zone thus confirming VT is a climate change adaptation technology (Booche *et al*., 2000 and Oku *et al*., 2011). Significant amount of carbon and nitrogen were loss under UP when compared with VT fields. These are converted to carbon dioxide and nitrous oxide that contributes to greenhouse gases in the atmosphere. Carbon sequestration and greenhouse gases mitigation potentials of VT are confirmed in the field. The vetiver technology sequestered 54-80 % carbon and 21-22 % nitrous oxide when UP was used as a control. Thus VT showed a positive contribution to reducing and removing greenhouse gas from the atmosphere (FAO, nd). Maize and cassava yield significantly increased in VT fields as a result of improvement in water economy (reduced runoff and increased infiltration). The UP fields did not only produce the lowest maize and fresh cassava tuber yields, but the yields also declined in the second year in UP fields, but increased under VT.

Conclusion

The practice of using vetiver as a green farming technology increased water and nutrient use efficiency and creates resilience. This allows the field crops adapt to low or inadequate rainfall during the growing period with increase and sustainable yields. The practice also, mitigates greenhouse gases emissions by reducing carbon and nitrogen losses from the soil. It is recommended that the capacity of smallholder farmers could be developed in the use of this green farming technology. In addition, Agricultural Extension Officers' capacity in this technology be developed for the sustenance and scaling-up of the technology.

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D4

Non-timber forest products, climate change resilience and rural poverty alleviation in northern Ghana

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Abstract

Climate change resilience is intricately linked to poverty alleviation for the reason that majority of rural dwellers, especially in developing countries, depend on nature for their livelihoods. Consequently, large sections of the population in rural areas in Sub-Saharan Africa are exposed directly to the negative effects of climate change, such as frequent of crop failure, and famines, thereby challenging existing livelihood systems. Non-timber forest products (NTFPs) constitute a substantial component of forest related livelihoods in Northern Ghana. Rural people have exploited NTFPs of both plant and animal origin for income, food and medicine for centuries. Although this group of off-farm products constitute a critical component of the ecosystem they have not been given adequate attention regarding their potential role in improving resilience of agricultural systems to climate change. Rather, they appear to be regarded as adverse to agricultural development. In this paper it is argued that NTFPs, as an integral component of landuse systems in Northern Ghana, will enhance the resilience of agricultural systems to climate change thereby translating into gains in income, food security and eventually, poverty alleviation. Indeed recent literature has shown that the contribution of NTFPs to rural livelihoods has been underestimated[1] and their inclusion in policies on landuse can enhance poverty alleviation impact[2]. This paper is derived from a study on the contribution of NTFPs to rural livelihoods in Northern Ghana. 288 respondents were sampled from households in 9 administrative districts. The study employed a combination of household surveys, focus group discussions and market surveys to generate data. The result revealed the significant contribution of NTFPs to rural likelihoods in Northern Ghana and demonstrates the need for re-thinking the role of NTFPs in climate resilience strategies not as a passive safety net but more rigorously as part of an integrated strategy for resilience of agricultural systems.

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D5

Jatropha production in Malawi and Mozambique: delineating ecosystem services and human wellbeing trade-offs

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Jatropha curcas is a biofuel feedstock that gained prominence in southern Africa since 2005. It was branded as a "miracle crop" due to its perceived development benefits based on promises of high yields, low water requirement, ability to grow on marginal land and lack of competition with food. In less than 10 years, tens of thousands of hectares were acquired for jatropha cultivation and thousands of hectares were planted, most of which are now unused or abandoned. At the same time, jatropha has been associated with a number of environmental and socioeconomic impacts such as GHG emissions, habitat/biodiversity loss, income/employment generation, energy security, food security and social conflicts. These impacts can be positive or negative depending on a number of factors but the knowledge about the emerging trade-offs has been rather incomplete for southern Africa.

The aim of this presentation is to identify the main trade-offs associated with jatropha production in southern Africa. We employ the ecosystem services approach to put into perspective the main trade-offs of two very different modes of jatropha production, i.e. a large plantation (Niqel, Mozambique) and a smallholder scheme (BERL, Malawi). In contrast to most jatropha projects in southern Africa that had collapsed, the selected projects were operational at the time of study (March 2013). By identifying what seems to be working in these projects we provide insights as to why other projects may have failed in southern Africa and whether there is still place for jatropha in the region.

We found that for both projects the main trade-offs involved provisioning services, and particularly the displacement of food crops by fuel feedstock. The magnitude of this displacement due to land use change was relatively limited as farmers in Malawi were incentivized to grow jatropha in hedgerows surrounding their family farms, while in Mozambique given the low population density and abundant land the displaced family farmers could clear woodland to relocate their family farms. However in the case of Mozambique there was also a potentially significant displacement of access to forest products and a degradation of climate regulation services considering that the plantation was established on converted woodland. However at the point of fieldwork actual jatropha oil production had not commenced so it was impossible to ascertain the magnitude of total greenhouse gas emissions through a life cycle assessment.

The main human wellbeing benefits accrued through the provision of income to jatropha growers (Malawi) and a stable salary to plantation workers (Mozambique). However, these monetary benefits are not captured evenly between community members. We identified that family farmers in Malawi with larger plots of land (and usually better off) were the most likely to adopt jatropha as a cash crop. On the other hand those most likely to be engaged as waged labor in plantation (in Mozambique) tended to come from less well-off and well-endowed households. In the case of the large plantation less tangible (but more widespread) human wellbeing benefits manifested through the improvement of road infrastructure, local schools and health clinics by the company.

Though the long-term sustainability of the two projects is not proven, both projects may increase resilience by diversifying household income streams. For example, both jatropha farmers and plantation workers indicated through interviews and focus groups a potentially positive effect on food security. This was due to the fact that the income obtained from jatropha allowed them to buy food in times of need (i.e. after drought, at end of crop calendar year), despite the displacements of labour (for plantation workers, smallholders) and land (for smallholders) from the subsistence agriculture prevalent in both areas.

Keywords: *jatropha, impacts, smallholder scheme, large plantation, southern Africa*

D6

Changing diet to cope with climate change: exploring innovative pathways for developing ready-to-eat millet products through integrated millet development initiative

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Abstract

Traditionally, peasant farmers in the Northern Savannah Ecological Zone (NSEZ) of Ghana have coped with the region's fragile ecosystem and the effects of climate change by developing complex inter-cropping systems and cultivating drought resistant crops such as millet and sorghum. Today, these systems are breaking down as a result of the cumulative effects poor yields per acre and a shift in dietary practices from consumption of home grown millet to consumption of imported rice and maize. The crop potentially occupies a strategic position in the country's food security focus alongside rice, cow pea, cassava, soybean and yam. Millet provides farm households, produce buyers, processors, exporters and transporters with sustainable income. Ghana is now a net importer of cereals which means the existing local market is massive. Millet is an important cereal crop due to its incredible resilience to the effects of climate change. As a result of its high nutritional content, there is the need to exploit the value chain of the millet crop through conscious agro-processing into ready meals such as pastries, pudding, weanimix, fast food/meals; malt, soft drinks (beverages) and other brewery products. The farmer in northern Ghana and all the other actors in the value change of the millet crop face a bright future, but that future is in the past. The position here is that, millet production and consumption can be boosted if; (1) there are opportunities increase farm size and yield per acre and; (2) developing innovative ready-to-eat products from millet that can be sold by street vendors and markets. An Integrated Millet Development Project (IMDP) holds the key. This involves capacity building through skills training and technology transfer; policy and institutional support; technical expertise and entrepreneurial skills development in the millet industry to provide more job opportunities for out-growers to restore agriculture's lead in the GDP league.

D7

The role and nature of trust in risk communication: insights from climate-induced risks prone rural communities in Wa West district, Ghana

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Abstract

A realistic risk communication system is inevitable for better awareness and preparedness creation especially I rural communities vulnerable to climate change related disasters. In many parts of Africa, programs have been initiated by the local governments and civil societies geared towards developing timely seasonal forecast and early warning systems to prepare the communities against risks. These measures include adopting drought tolerant crops, appropriate soil moisture farming techniques, and instituting efficient evacuation plan. However, recent studies have catalogue many instances of failure primarily because conventional risk communication strategies over-emphasize the contents of the information, to the detriment of information source. This paper argues that since climate change induced risks are uncertain and complex, individuals decision-making depend much on their trust in the risk information source. The study thus systematically examines the role and nature of trust in risk communication strategies, maintaining that familiarity with a hazard information predicts the relative trust attached to it which is also influenced by the community's social and cultural characteristics.

D8

Material flow analysis for Shea butter production systems and ecological sustainability in Ghana: an exploratory study

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Abstract

The continuous support of the environment for human activities is largely determined by the quantity and nature of the associated material flows. The material input to the economy from nature and output to the environment can be accounted for and useful lessons drawn for society and ecological sustainability. The notion of Non timber forest products (NTFPs) is to ensure that provisioning services continue to be available to support livelihoods whilst reducing deforestation. Many improvements and innovations are taking place in the processing of Shea nuts in to butter and other value added products in response to local as well as international market demands. The processing however, require use of fuel wood for heating and a lot of water use in the production process. The nature of the input requirement and production process presents implications for social, economic as well as environmental sustainability. Using material flow analysis (MFA), this paper shows the process and physical material flows and quantities within domestic and export loops in the production system. Taking rural and urban locations for traditional and Semi-mechanized Shea butter processing, this paper computes the associated economic value (resource use efficiency) and environmental value (deforestation and carbon footprint) as indicators for sustainability of the Natural Capital for the associated material flows. Data was collected from 40 rural processors in 4 villages and 12 urban Shea processing sites in Wa and Tamale in Upper West and Northern Regions respectively. Physical measurement of water required, wood mass burnt as fuel and labor used per unit production cycle. Interviews and questionnaire administration supported were used as well. The results present a qualitative flow of materials involved in the Shea production for Shea Kernel and crude butter production. It also shows the most efficient resource use thresholds in crude butter production with accompanying area of deforested and implications for environmental sustainability.

Keywords: *Material Flow Analysis, Shea Production Systems, Resource use efficiency, Environmental Sustainability, Natural Capital, Ghana*

D9

(Presentation Cancelled)

Investigating the sensitivity of household food security to agriculture-related shocks and the implication of informal social capital and natural resource capital: the case of rural households in Mpumalanga, South Africa

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Abstract

Resource-poor rural South Africa is characterized by high human densities due to the historic settlement patterns imposed by apartheid, high levels of poverty and substantially high food insecurity. Chronic food insecurity combined with climate and weather variability has led to the adoption of less conventional adaptation methods in rural resource-poor settings. This paper therefore examines the impact of agriculture-related shocks on the consumption patterns of rural households. In our assessment we are particularly interested in the interplay between social capital (both formal and informal), natural resource capital and agriculture-related shocks. We use a relatively new and unique three years Sustainability in Communal Socio-Ecological Systems (SUCSES) panel of households from rural Mpumalanga in South Africa who rely on small-scale homestead farming. Overall we make two key

observations pertaining to rural settings. First, the shocks reduce households' food availability and thus consumption. Second, natural resource capital (e.g. bushmeat, edible wild fruits, vegetables and insects) and informal social capital (ability to ask for food assistance from neighbours, friends and relatives) somewhat counteracts this reduction and sustains households dietary requirements. In general, our findings suggest the promotion of informal social capital and natural resource capital as they are easier, cheaper and more accessible alternatives to household coping strategy, in comparison to other more technical and capital intensive strategies such as insurance, which remain unaffordable in most rural parts of sub-Saharan Africa.

Keywords: *agriculture-related shocks, caloric consumption, natural resource capital, informal social capital, formal social capital, weather-related crop failure, small-scale-subsistence farming households*

D10

Adaptive co-management of forest resources: a case of Takamaru-yama Sennen-no mori, Tokushima, Japan

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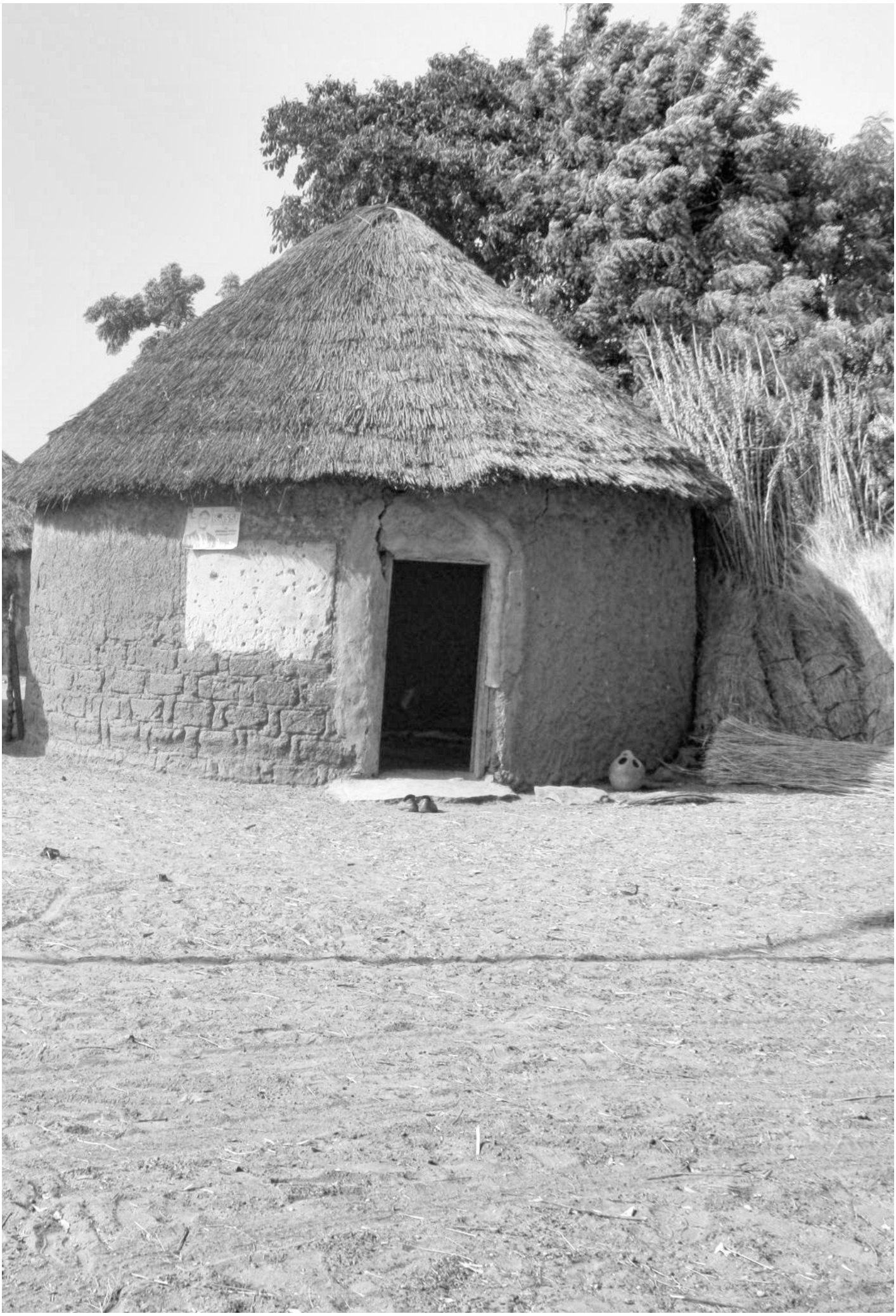
Abstract

Takamaru-yama Sennen-no mori (TYSM: Thousand-year Forests in Mount Takamaru) was initially established by Tokushima prefecture (one of the four prefectures consisting of the island of Shikoku, Japan) and now operated by Kamikatsu Satoyama Club (KSC). The KSC itself is a consortium of 10 local organizations (i.e., NPO, local companies, and study groups). The KSC, in consultation with the local Tokushima government, academics and professionals, and local citizen groups, plans and organizes forest nurturing projects such as native forest regeneration and environmental education. The KSC provides opportunities for interaction among different groups, such as urban residents and rural residents, and people with different interests on the use of forests, through year-round programs and activities. While this type of active adaptive co-management (adaptive and collaborative management) of natural resources (in this case, forests) by local entities with diverse interests is considered ideal, in Japan there are more unsuccessful cases of management where only the government bodies are involved in the management with little local input, or where the transition of power to manage from the government to local groups has failed. The TYSM and its designated manager, KSC, are presented as one of the few successful examples of (1) the successful transition of power to manage from the government to the local interest groups, (2) two-way sharing of knowledge between the academics/professionals and local residents, and (3) locally-led, adaptive co-management/governance of natural resources.

Researchers of the University of Tokushima have been involved in forest regeneration in the TYSM and the establishment of the KSC since its early conceptual stage. Cypress (*Cryptomeria japonica* and *Chamaecyparis obtusa*) plantations occupy 28% of the total forest area in Japan. They were planted all over Japan about 40 years ago, encouraged by the Japanese government. Due to several factors that have led to the decline of forest industry in Japan, the plantation forests have not been properly maintained and some even left abandoned. Consequently, these plantation forests with closed canopy and little understory or ground cover have little biodiversity and offer few ecosystem services. The local Tokushima government and some university researchers have been involved in finding ways to regenerate native broadleaf deciduous forests once rich in plants and animals. The key here is that the linkage between the locals and the secondary forests (native broadleaf deciduous forests) has been lost. The KSC was established to regain the lost linkage and nurture native forests through forest regeneration and environmental educational programs to connect urban residents with rural residents, and people with different interests in terms of the use of forests. The KSC acts as an organizer and coordinator of various activities and interests. It encourages interaction among various interest groups through these activities. It plays multiple roles: a planner, an organizer, a natural resource manager, an educator, and a facilitator. This kind of collaborative co-management system is arguably a rare successful case in Japan and even in the world. The lessons learned from this case have implications for successfully managing the natural resource base in the northern Ghana.

Keywords: *Adaptive co-management, local knowledge, natural resource management, forest regeneration, environmental education*



Thursday 7th August 2014

13:30 – 17:00

ABSTRACTS

SESSION E

E1 » 10

Implication of Climate and Ecosystem Changes on Agricultural Production (II)

E1

Integrated assessment of vulnerability of rural households to climate stress across regional levels in Niger

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Research question

To which extent are rural households vulnerable to climate stress and what are the underlying factors?

Abstract

Based on household-level survey data collected from the national institute of statistics, vulnerability as an expected poverty approach (Chaudhuri et al. 2002) is used to analyse the probability of rural households falling below the poverty line (minimum income) due to climate shocks. Logistic regression is used to estimate the proportion of rural households with an income below the income threshold (vulnerable households) and the result shows that 77% of rural households have their income below the poverty line. While there is a negative effect between flood occurrence and the risk of having an income below the poverty threshold, the correlation is positive with drought occurrence, meaning that flooding is likely to decrease the probability of being poor, whilst drought occurrence causes households to suffer from poverty.

This study is also based on vulnerability resilience indicator across regional levels following Temesgen Deressa, Rashid M. Hassan and Claudia Ringler (2008). The resilience is computed as the net effect of exposure and sensitivity on adaptive capacity and the higher net value the lesser vulnerability. The result shows that rural households living in the regions of Dosso and Tahoua are relatively less vulnerable than those of the five other regions of which those of Zinder and Niamey are the most sensitive and exposed to climate stress.

Methodology

a) Measuring vulnerability as expected poverty using logistic regression by means of maximum likelihood (Chaudhuri et al. 2002).

$$P(y_i < \bar{y} \mid x_i)$$

Where y_i is the per capita income per day of individual i as dependent variable, $\bar{y}$ is the existing poverty threshold in the area of concern and x_i are households' characteristics and environmental shocks.

$$\mathbf{Prob(Y_i < \overline{Y} | X_i)} = \frac{\mathbf{e^{X'\beta}}}{\mathbf{1 + e^{X'\beta}}} = \mathbf{Prob(Y = 1 | X_i)}$$

$$\frac{\partial \mathbf{Pr}\,[y_i = \frac{\mathbf{1}}{X_i}]}{\partial x_{ij}} = F'(X_i'\beta)\beta_j$$

The marginal effects measure the expected change in probability of income with respect to a unit change in an explanatory variable.

b) Vulnerability resilience indicator using weights from principal components analysis PCA (Deressa et al., 2008)
The index formula for a given region j is given by:

$$I_j = \sum_{i=1}^{k} w_i (x_{ij} - \overline{x_i}) / \sigma_{x_i}$$

Where w_i is the weight for the i^{th} indicator in the PCA model, x_{ij} is the j^{th} region's value for the i^{th} indicator, $\overline{x_i}$ and σ_{x_i} are respectively the mean and standard deviation of the i^{th} indicator for all regions. From the equation above we can generate the associated index for adaptive capacity, exposure and sensitivity for each region:
Adaptive capacity index of region j for the i^{th} indicator:

$$A_j = \sum_{i=1}^{k} w_i^A (x_{ij}^A - \overline{x_{ij}^A}) / \sigma_{x_i}^A$$

Exposure index of region j for the i^{th} indicator:

$$E_j = \sum_{i=1}^{k} w_i^E (x_{ij}^E - \overline{x_{ij}^E}) / \sigma_{x_i}^E$$

Sensitivity index of region j for the i^{th} indicator:

$$S_j = \sum_{i=1}^{k} w_i^S (x_{ij}^S - \overline{x_{ij}^S}) / \sigma_{x_i}^S$$

Vulnerability resilience indicator of region j for the i^{th} indicator:

$$VRI_j = A_j - (E_j + S_j)$$

$$VRI_j = \sum_{i=1}^{k} \left\{ \frac{w_i^A \left(x_{ij}^A - \overline{x_{ij}^A}\right)}{\sigma_{x_i}^A} - \left[\frac{w_i^E \left(x_{ij}^E - \overline{x_{ij}^E}\right)}{\sigma_{x_i}^E} + \frac{w_i^S \left(x_{ij}^S - \overline{x_{ij}^S}\right)}{\sigma_{x_i}^S} \right] \right\}$$

E2

Gender and adoption of cowpea innovation in the context of climate change in Benin

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Abstract

Cowpea is a substantial source of food and incomes for rural farm households. However the extreme variability of climate decreasing cowpea production requires the development and adoption of new technologies including a wide range of short, medium and long cycle varieties; adapted crop production, protection practices and related knowledge and information for both men and women farmers. The overall objective is to assess the gender related adoption of climate smart technologies to mitigate the negative effects of climate change. A sample of 120 producers was selected according to gender disaggregated data and climate change indicators most relevant respectively in two area of Benin: Collines and Couffo regions. The analysis is based on the descriptive statistics and particularly frequencies and proportions.

The results showed us that although the producers are aware of the effects of climate change but the resources they have to deal with are still very limits. We also note a prevalence of endogens methods in farming practices, more present in women than men. Even if areas receive the same problems of climate change, the impact on women and men are not the same. Cowpea producers cited improved technologies and traditional technologies such as strategies for climate change adaptation in. These technologies are short cycle improved varieties tolerant to drought, endogenous methods, botanical extracts, ash animal urine and black soap. Majority of women use black soap and botanical extracts because of their low income. Producers are informed on the availability of new seed varieties, but often do not have access to these inputs.

Keywords: *Climate change, technologies for adaptation, Income distribution, innovations*

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E3

Response of maize to climate adaptation strategies in the Sudan savanna of West Africa

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Abstract

An on-farm researcher managed experiment was conducted in three representative sites of the Sudan Savanna Zone of three West African countries: Ghana (Vea), Republic of Benin (Dassari) and Burkina Faso (Dano) in 2012. The aim of the experiment was to evaluate the effect of tillage practices and nitrogen fertilizer regimes on the yield of a short season maize (*Zea mays* L.) variety, DORKE SR, for two landscape positions. The experiment was carried out as a stripe-plot design with four replications at each of the three sites. Tillage practices (contour and along ridges) were allotted to main-plots whereas nitrogen treatments (no nitrogen-0 kgN ha^{-1}, moderate nitrogen-60 kgN ha^{-1} and high nitrogen 120 kgN ha^{-1}) made up the sub-plots treatments for each landscape position (upslope and footslope). Across the three sites both potassium and phosphorus fertilizers were applied at 40 kgK_2O ha^{-1} and 60 kgP_2O_5 ha^{-1}. Grain yield, aboveground biomass, LAI, plant height and phenology showed diverse responses with respect to tillage, slope position and nitrogen fertilizer regimes across sites. The impact of slope position and nitrogen fertilizer regimes were significant ($p<0.05$) across sites for grain yield leading to an increase of 29.2% and 125% for footslope and high nitrogen regime, respectively, as compared to upslope and no nitrogen fertilizer regime across sites. A trend for higher grain yields in Dassari and Dano was noted for contour tillage though differences were not significant at $p<0.1$ compared to ridges oriented along the slope. At Vea, the impact of tillage was significant ($p<0.1$) and contour ridges recorded approximately 25% higher grain yield than the along slope-ridges. Nitrogen fertilizer regimes significantly ($p<0.1$) influenced LAI at tasseling between sites and values were consistent with increasing nitrogen levels. The importance of these results to farmers relates to the fact that for optimum maize yield under sub-humid conditions, it is recommended to concentrate maize cultivation at the low lying areas in combination with contour tillage with the recommended fertilizer application.

E4

Trends in NDVI and relationship with rainfall, population density and land use land cover change over the Bani River Basin (West Africa)

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Abstract

Global monitoring of vegetation with remote sensing helps understand the linkages between vegetation, climate, and anthropogenic activities. Changes in land use resulting from population growth have triggered interest from research to investigate in more detail causal relationships between trends population density, rainfall patterns and vegetation dynamics. The goal of this research is to assess such relationships in the context of perceived greening and degradation trends over the Bani river basin. The Bani is a northern flowing tributary of the Niger [9°17' to 14°18' North and 4°10' to 8°12' West] spanning the North Guinean, Soudanian and Sahelian agro-ecologies. A 30-year, 8-km gridded rainfall dataset was produced by inverse distance weighted (IDW) interpolation of monthly data from 40 meteorological stations contained within the basin. Gridded Population densities were retrieved from National population statistic for 1987, 1997 and 2009 census and interpolated at district (commune) level. An 8 km Normalized Difference Vegetation Index (NDVI) from 1982 to 2011 was created using SPOT Vegetation 1 km and GIMMS 8 km reference data. Time series trend of rainfall and NDVI for the 30 years period have been analysed. The relation between rainfall and NDVI at pixel level, in one hand and, and NDVI and population densities on the other hand have been carried out considering the district boundary. Land Use Land Cover Conversion (LULCC) rates were computed for the same period using Landsat imagery and ground surveys at 4 anchors sites: Dieba, Sibirila, Sukumba and Nompossela. Trend analyses reveal that within the Bani river basin, vegetation greening trends are mostly associated with areas where natural vegetation is still well represented. Concurrent with increases in rainfall over the period analysed, this finding supports the hypothesis that re-greening observed in that area is the result of multi-decadal fluctuations in climate, rather than improved land management.

E5

Impact of flood on the livelihood of farmers in semi-arid zone of Benin Republic

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Brief introduction

River flooding has become a widely distributed and devastating natural disaster that has caused significant damages both economically and socially. According to different studies, Benin has recently been affected by changes in seasonal patterns, reflected in the occurrence of new stresses, and /or increased climate variability (Ago *et al*., 2005; IPCC, 2007). As people cultivate more land than before, and a greater proportion of this new land is located next to the river, and so more liable to flooding, locals are now more susceptible to the devastating effects of floods. In Benin floods have always taken place, and they are not always related to heavy rains in the local area but sometimes to heavy rain upstream (Cuni-Sanchez *et al*. 2012). Since 2007, Benin has experienced frequent floods. The recent and severe one occurred in August 2010 when 55 townships out of 77 were affected. Agricultural experts had warned of huge damage to land and livelihoods in rural communities. Relief agencies and the government of Benin have appealed for US$46.8 million to help the nation recover from the worst flooding in nearly 50 years (IRIN 2013). The impact of these floods on Benin economy was captured through the analysis of damage and losses. The damage caused by 2010 flooding amounted to 78.3 billion CFA francs (about USD 160 million) and was related to total or partial destruction of assets including buildings and what they contain, infrastructure, inventory, etc. The losses amounted to 48.8 billion CFA francs (approximately USD 100 million) (World-Bank, 2011). In semi-arid zone of Benin republic, the last flooding events occurred in August 2012 and 2013, when many farmers lost most of their crops. Yet, no studies were conducted to yield comprehensive data on the level of damage local communities have gone through after the flooding of 2012. Then the agricultural economic impact of flood at household levels is needed in order to contribute to the scientific debate of positive/negative impact of flooding (Khakbazan *et al*., 2013;

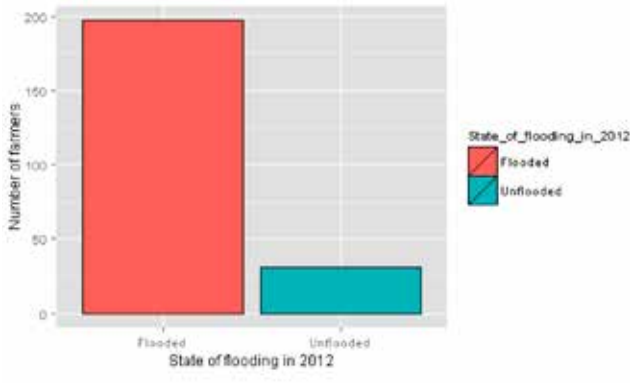

Figure 1: Number of farmers flooded and unflooded in 2012

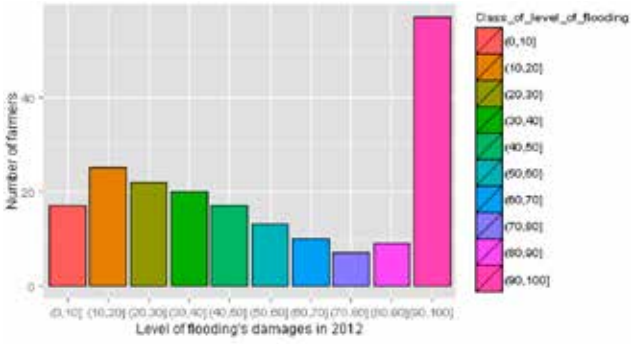

Figure 2: Number of farmers per categories of flooding damages in 2012

Nkeki *et al.*, 2013; Ojeh *et al.,* 2012; Pauw *et al*., 2011; Baudoin *et al.*, 2013).

Materials and methods

To fill in this gap, a survey is conducted in semi-arid zone of Benin republic in Benin, a small country south of the Sahel. Two townships are chosen: Malanville and Karimama because of their location in downstream. In this region our focus is the villages near a river. Then 9 villages in Malanville out of 19 recorded were surveyed. While in Karimama, 10 out of 13 villages recorded were surveyed. A stratified random sampling procedure is applied to strata with high, medium and low flood probabilities. A total of 19 villages were chosen with 12 farmers interviewed in each village, leading to a total of 228 farmers are interviewed. That represents 3.82% of the total farmers recorded in the 32 villages. The questionnaire includes open and closed question and concerned: socio-demographic characteristics of the household, History of farmer about flooding, household farm characteristic during the rainy and dry season 2012-2013, agricultural income of household during growth season 2012-2013, additional expenditures does flooding bring and flooding prevention and adaptation measures. A non-experimental approach known as a Propensity Score Matching (PSM) is used to measure the impact of 2012 flood on farmers' revenue in semi-arid zone of Benin republic (Gertler *et al.,* 2011) using the software R with the package MatchIt (Ho *et al*., 2011).

Results and Conclusion

Results show that 86.4% (197 farmers) of farmers surveyed had their farms damaged by flooding in 2012 (**Figure 1**). In this subset, the average flooded size of farm per household after 2012 flooding is about 2.4 hectare. The 25% of the sample (57 farmers) lost almost the total cultivated area during this flooding. (See **Figure 2**). The average agricultural income of flooded farmers after 2012 flooding is XOF 527,139 ($US1054) while it is XOF 593,625 ($US1187) for non-flooded farmers. Overall the econometric model indicates that flooding has a negative and significant impact on farmer agricultural revenue about on average USD 500 per farmer. To cope with this worse situation, farmers develop many adaptation and prevention strategies as shifting the cultural calendar and diversification of activities.

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E6

Rice farmers' vulnerability to climatic variability: quantitative evidence for adaptation resource allocation from Ekiti State, Nigeria

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Background Information

Impacts of climate change are increasingly visible around the world, from dwindling water supplies, crop-damaging heat waves and droughts, and to ecological disasters. In this context, assisting vulnerable communities to adapt and protect themselves has been recognized as an increasingly pressing issue by the international community. Progress has been made in securing pledges for finance to assist developing countries with both mitigation and adaptation, but the current system is fraught with obstacles, complexities, and unsettled debates. At the 2009 United Nations Framework Convention on Climate Change (UNFCCC) Summit in Copenhagen and the 2010 meeting in Cancun, developed countries affirmed their commitment to assist developing nations with addressing climate change by providing an initial US$30 billion in "Fast-Start Finance" (FSF) from 2010-2012 and contributing toward a global climate finance target of US$100 billion yearly by 2020. However, there are some claims that as of the middle of 2011, only about 8% of the pledged FSF had actually been disbursed (Intergovernmental Panel on Climate Change, IPCC, 2007).

Developed countries have been criticized for a lack of transparency in how they are distributing and accounting for these funds (IPCC, 2012), the larger share of climate finance has thus far been spent on mitigation activities, prompting calls for an increased allocation for adaptation (World Bank, 2010). Many developed countries and international institutions have already begun providing climate finance to developing countries but rather than pursuing a coordinated or streamlined approach, a proliferation of climate finance mechanisms has occurred (Venton and LaTrobe, 2008). This large number of funds includes the national funds such as the National Climate Change Trust Fund and the Environmental Sustainability Group in Nigeria, etc in addition to many bilateral programmes. This confusing web of funds puts burdens on developing countries and increases the challenges of coordinating and accessing finance (Mitchell *et al.,* 2010). The difficulty of tracking climate change finance has spawned several attempts to map many channels and mechanisms. There is no formal and transparent methodology for allocating funds between projects at the sub-national level (Harris and Bahadur, 2011). Given the limited resources available to support adaptation to climate change impacts, it is crucial that funds be deployed equitably and efficiently. There are efforts in place to strengthen the capacity of vulnerable communities and local governments to meet adaptation needs, therefore this study will provide a basis for further discussions around which policies can be made to ensure efficiency in allocating adaptation resources at a local level in Ekiti State, Nigeria.

Materials and Method

The study area was the derived savannah-forest agro-ecological zone of Ekiti State. Ekiti State has an approximate population of 2, 748, 441 with an estimated land mass of 10,898.68 sq.km located entirely in the tropical part of southwest Nigeria (Ekiti State Government, 2010). It possesses two Agro-Ecological Zones (AEZs) namely the tropical forest in the South, and derived savannah in the Northern peripheries. Ise Orun Local Government Area (LGA) situated within 5°31'E, 7°34'N was selected from the southern forest zone while Oye LGA between 5°37'E, 7°76'N was represented the derived savannah zone (See **Figure 1**).

Data, Sampling Techniques and Data Collection

Primary data collected from field survey were used to obtain relevant socioeconomic data of selected rice producers on their sensitivity, exposure and adaptive capacity across the agro-ecological zones (AEZs). A multi-stage sampling technique was used to select eighty-seven (87) respondents in which *Oye* LGA purposively selected to represent *Derived savannah* and *Ise Orun* LGA in the *Tropical forest* zone. Secondary data of the observational daily weather data on maximum temperatures, minimum temperatures, and rainfall were obtained for the available year 2010. Exposure variables in the climate change composite vulnerability index (CCVI) were selected from daily meteorological data of the Climate Forest System Reanalysis (CFSR) downscaled at 38km resolution from the National centre for Environmental Prediction (NCEP) over the twelve months of 2010. The daily data were reduced to monthly averages while standard deviations were estimated to determine the trends of climatic variability.

Quantitative Estimation of Vulnerability Index

The vulnerability status of the sampled rice farmers to climatic variability and extremes was determined by computing Climate Change Vulnerability Index (CCVI). In each community, a set of indicators were selected for the three components of

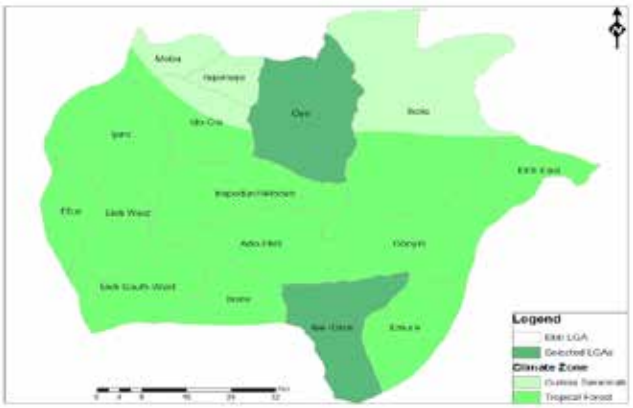

Figure 1. Map of Ekiti State Showing the Study Area

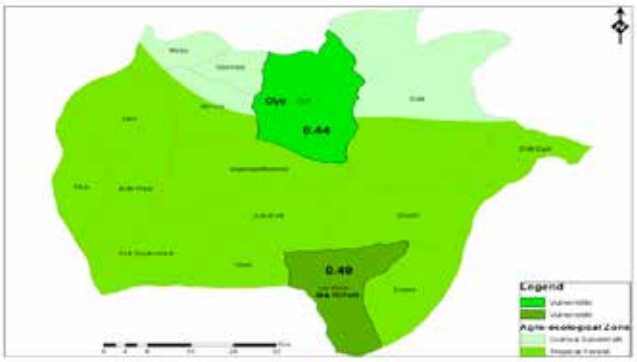

Figure 2. Vulnerability map of rice farmers in the study area

Table 2. Disaggregated component index of climatic vulnerability

AEZ	Exposure	Sensitivity	Adaptive capacity	Vulnerability Index	Rank
Tropical forest	0.01	0.05	0.03	0.49	1
Derived savannah	0.03	0.05	0.02	0.44	2

Source: Field data, 2013.

vulnerability. Dimensions of subgroup indicator were identified. Indicators were then selected based on data availability, personal judgement and previous studies. Implicitly;

CCVI (of community *i*) = V_i = [Exposure + Sensitivity - Adaptive capacity]
where, V_i =*Climate change Vulnerability Index*,
E_i = Exposure to hazards; S_i=Sensitivity; A_i = Adaptive Capacity

Multivariate analysis (Principal Component Analysis) was conducted to choose valid indicators. Indicators were then normalised in order to obtain figures which are free from the units and scales. After giving consideration to the functional relationship between the indicators and vulnerability, the value 1 from the Min-Max normalization equation corresponds to that community/AEZ with maximum value and 0 the otherwise (Briguglio, 2003). Weighted average technique was used to compute a composite vulnerability index by assigning heavier weights to those indicators that contribute the greatest amount of variance. The weights were assumed to vary inversely as the variance over a local government area in each indicators of vulnerability (Iyengar and Sudarshan, 1982). The indices were ranked by degree of vulnerability based on linear intervals such that each interval has same probability weight of 20% which categorized the levels of rice farmers vulnerability in the study.

Results and Discussion

Vulnerability ranking of respondents by agro-ecological zone

The CCVI shows that Ise-Orun LGA is more vulnerable than Oye. Ise Orun in the forest zone has a higher index of 0.491 compared with 0.440 in Oye on the vulnerability scale. Rice farmers in the tropical forest zone are more vulnerable to climatic variability and extremes than those in Oye, though they were still on the same interval scale. This result confirms previous studies that vulnerability to the impacts of climatic changes/variability and extremes does not follow geographic location or topographic landscape. Other important parameters are also responsible for such differences in vulnerability that do not follow normal expectations (See Awolala, Ajibefun, and Imoudu, 2014). The vulnerability map is shown in **Figure 2**.

Disaggregated sub-component vulnerability indices

The vulnerability composite components presented in **Table 2** explains that sensitivity component was the highest across the AEZs, exposure and adaptive capacity indices were comparably lower although they were on equal averages. Rice farmers in the Tropical forest Zone (Ise Orun) had a higher adaptive capacity but lower in the Derived savannah (Oye) while exposure component is higher in Oye than Ise Orun.

Sensitivity subcomponents indicators and rice farmers' vulnerability

Figure 3 shows the magnitude of each sub-component of sensitivity variable contributed to the overall CCVI rank scores in Ise Orun and Oye LGAs respectively. Critical observation reveals that socio-economic variables were major contributors to vulnerability in the Tropical forest zone while it is human capital in the Derived savannah. Therefore, agricultural, geographic, and human capital factors were not important to increase in the level of vulnerability in the forest Zone.

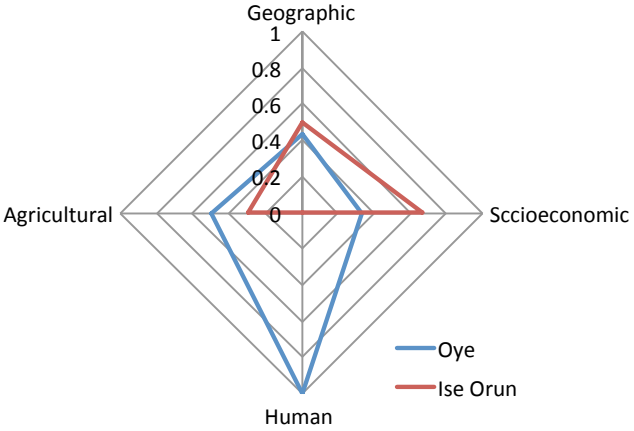

Figure 3. Disaggregated sensitivity component indicators

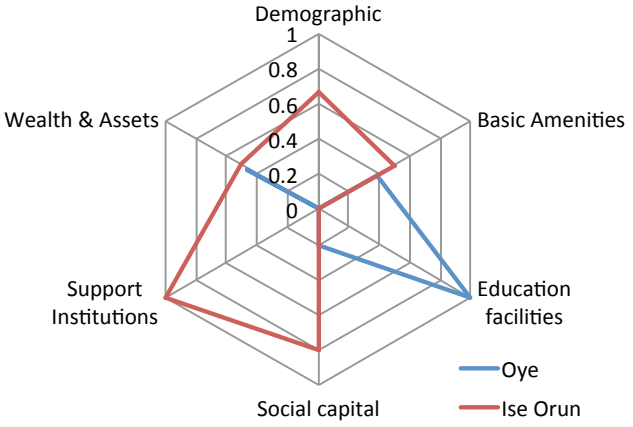

Figure 4. Disaggregated adaptive capacity component indicators

Adaptive capacity subcomponents indicators and farmers' vulnerability

Figure 4 provide insight that wealth and assets, education infrastructure, and basic amenities were not important contributors to adaptive capacity in Ise Orun (Tropical forest) while education infrastructure in Oye (Derived Savannah) is the only major sub-component reducing farmer's vulnerability. However, presence of support institutions in Ise Orun serves as a major coping strategy to reduce vulnerability. Outside inadequate support institutions, there were other factors responsible to higher vulnerability in Ise Orun in comparison with other components of vulnerability.

Summary and Conclusion

The CCVI estimation reveals that Ise-Orun is more vulnerable than Oye. Rice farmers in the tropical forest are more vulnerable to climatic variability and extremes than those in derived savannah. The sub-components of sensitivity reveals that socio-economic factors contribute higher to reduction in vulnerability in the tropical forest while human capital variables are also higher in derived savannah. Inadequate agricultural supports, geographic and human capital variables were responsible for higher vulnerability in tropical forest unlike derived savannah. Wealth and assets, education infrastructure, and basic amenities were not important to adaptive capacity in the forest zone. Other factors are responsible to higher vulnerability in the tropical forest outside inadequate support institutions considering other components of vulnerability.

The application of Climate Change Vulnerability Index, (CCVI) can assist the local residents, decision makers, donor organizations, and government in making decisions with regard to interventions that would reduce farmers' vulnerability in the tropical forest. Larger adaptation fund allocation and resources should be directed towards increasing farmers' adaptive capacity in Ise Orun first because of lack of government supports and infrastructure than Oye. The continuous monitoring of the CCVI computation will provide a pointer on the development scale over time and give reliable information for adaptation finance or resource distributions towards local government financing mechanisms, and broader development planning in the forest zone. Local government institutions should be allocated with climate change adaptation funding through direct transfers to offer them flexibility to use resources directly to locations of higher vulnerability rather than re-allocation based on political sentiments and/or politician's discretion.

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E7

Indigenous coping agricultural strategies of farmers to mitigate climate variability on farming in the Bawku West district of the Upper East region of Ghana

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Introduction

Farmers in northern Ghana have been and continue to depend mainly on rainfall for crop cultivation and agriculture as a major source of livelihood. Some communities have been assisted with irrigation dams to collect water for farming or animal watering during the dry season but sustainable availability of water in these dams still depends on rainfall in the single rainy season in a year. These farmers have been coping with varying rainfall for some time now in order to avert total failure of productivity in a cropping season. Scientists predict worsening future climatic conditions in the world; for instance, Reid *et al.,* (2009), noted yields from rain-fed agriculture could be reduced by up to 50% by 2020 in some countries. Climate models confuse us as some predict increase, whilst others predict decrease in rainfall amounts. Whilst some areas are experiencing flooding others are saddled with droughts with the poor in such communities being the most vulnerable in both cases as they lack capacity to adapt to the variations. This research was aimed at identifying the coping strategies being used by farmers in the Bawku West District in recent times as well as their views and experiences about the current climate relative to the past. This area was chosen because it is relatively peaceful and also because it is bounded by two tributaries of the Volta river to the north and south making it prone to flooding in times of extreme rainfall.

Materials and methods

Materials used to collect data were semi-structured questionnaire, checklist and tape recorder. Interviews and focus group discussions were used to collect data on the views and experiences of farmers in the study area about climatic variations and the coping mechanisms used. In-depth interviews were also held with some key informants in selected communities in the district.

The population for this study was farmers in the Bawku West District. Farmers were sampled from seven (7) communities in the district by first putting the district into clusters using the area councils in order to reduce travel and administrative cost. Seven clusters each representing an area/ town council was formed and a community was selected randomly from each cluster (area Council). A clustered design is one where more than one stage of selection is used with the advantage of reducing time and cost of the research and also simplifies the investigation while retaining almost the same degree of accuracy of a random sample (Osuola, 2001; Kumekpor, 2002). The snow ball sampling technique was used to ensure that female - headed households and the elderly in the community were included, (Adapted from Yeboah, 2005) as well as key informants such as assembly persons, magazias, chiefs,and "Tindana's". In all one hundred and thirty-five (135) people comprising of one hundred and five (105) farming household heads and thirty (30) key informants were interviewed in the District.

Secondary data for this study was literature taken from books, articles, and journals in various libraries and the internet.

The data gathered was analyzed using descriptive statistics such as frequencies and percentages and the results presented in tables, charts and graphs, using the Statistical Package for Social Sciences and Excel software's.

Results/discussion

The findings of the study showed that farmers have noticed variations in climate and their views on these variations are similar to those of scientists. They perceived that the climate is getting drier as they noted decreasing amounts of rainfall for a season, changes in onset and end time of rainfall and increasing incidence of flooding. Farmers pointed to a decrease in rainfall amounts for a season because it was reported to start late and end early but in actual fact seasonal amounts might not be decreasing but the distribution in the season might be the problem. They associated climate variability with spirituality as some of them think it is because they have wronged God. They seemed to have no idea about the activities of humans especially the emission of greenhouse destabilizing gases in the developed countries. Whilst a few of them did not know the causes, others attributed it to the improper use of some chemicals for farming.

The farmers have been trying to adapt to the adverse situation in various ways, such as soil moisture conservation, mixed farming and use of improved crop varieties with short growth periods with maize cultivation of varieties of short duration on the increase. Other coping strategies in the wake of changing climate were avoiding flood prone areas during the rainy season or planting early maturing crops, planting trees in flood prone areas. Farm management practices such as bush fallow, burning of crop residue and planting on flat farmlands were scarcely practiced, with more people ready to plant trees if given seedlings. They also engaged more in livestock rearing

especially goats and poultry because they are highly prolific and less expensive.

Conclusion

Coping strategies adopted by the farmers were mainly in the areas of soil moisture and fertility improvement measures but are not new, and appeared as intensifications. These intensifications might not to be sufficient as they are currently not able to improve crop yield and should these variations in climate become worse, farmers could be helpless.

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E8

Reducing greenhouse gas emission from ruminants through the use of indigenous browse plants

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Abstract

The study was carried out to investigate the in vitro methane production from wheat straw supplemented with three different leaves of tropical browse plants. Leaves of *Ceiba pentandra*, *Senna siamea* and *Gmelina arborea* were harvested at the start of dry seasons (October, 2011) in the Northern Region of Ghana. The leaves were shade dried and milled through a 2mm sieve screen. This was mixed with wheat straw in a proportion of 60:40 (wheat straw: leaves) and incubated in buffered rumen fluid using the continuous culture technique in a Latin square design. The results of the study showed that methane gas production was reduced by 38%, 19% and 19% when wheat straw was supplemented with *Ceiba pentandra, Gmelina arborea and Senna siamea* respectively. The in vitro gas production (IVGP) which is a measure of the extent to which the substrate is being digested by the anaerobic rumen microbes was in the range of 28mls/g DM to 37mls/g DM. The lowest IVGP was recorded in the *Ceiba pentandra* supplemented diet with the highest recorded in the unsupplemented wheat straw. The difference in the IVGP was however not significantly different. There was no significant difference ($p>0.05$) in pH and ammonia nitrogen of the media after 12hours of incubation. The study revealed that methane gas production of wheat straw reduced by 19-39% when supplemented with browse plants with the highest reduction recorded in *Ceiba pentandra*.

Introduction

The feeding of cereal based crop residue like rice straw is a very common practice in the Northern region of Ghana especially in the dry season. It serves as a readily available source of energy for ruminant during this period. Cereal based straws are often associated with high fibre and low nitrogen (Ansah *et al*., 2011). Highly fibrous feedstuff usually has a longer rumen retention time and reduces feed intake. Mills *et al.* (2003) suggested that increased feed intake results in lower methane gas production. Rumen fermentation of poor quality forage produces more methane gas than fermentation of better quality forages (O'Hara *et al*., 2003). Methane contributes 24% to global warming, and methane emission from rumen fermentation is the largest single source of methane (Hansen *et al*., 2000). According to IPCC (1996), Dairy cattle from Africa and the Middle East produce 36kg/head of methane annually. Condensed tannins, a plant secondary metabolite present in most browse plants have received great attention for its ability to reduce methane production (Carulla *et al.,* 2005). The present study seeks to investigate the extent to which methane gas is reduced when wheat straw is supplemented with different browse plants at 40% inclusion.

Materials and methods

Three browse plants were used as supplement to a low nitrogen containing straw in a proportion of 40% DM browse to 60% DM straw. The treatments were *Ceiba pentandra*+straw (CP+S), *Senna siamea*+Straw (SS+S), *Gmelina arborea*+Straw (GA+S). The samples were milled using a hammer mill with the aid of a 1mm sieve screen. Sole straw (SS) without any supplementation was used as a control. The 4*4 Latin square design was used for this study with each experiment (run) lasting a total of 14days. The first 8 days was used as an adjustment period with actual data collection commencing on the 9th to the 14th day. Rumen fluid was collected from 4 different rams fitted with a fistula. The animals had an average weight of 95kg and were fed on straw and concentrate (Wynnstay ram master coarse mix, UK) at a rate of 1.1x maintenance requirement (AFRC1993). Buffer was prepared according to the method of McDougall, (1948) and modified to contain 13.82mg/day (ammonium sulphate) $(NH_4)_2SO_4$ to supply 2.93mg/day of nitrogen. The

Table 1 Percentage chemical composition of experimental diet

Diet	DM	OM	CP	Ash	NDF	ADF	CT g/kg
SS	92.45±0.16	84.57±0.33	3.59±0.11	7.87±0.16	75.99±0.39	57.62±1.07	ND
SeS+straw	92.22±0.07	85.10±0.06	9.54±0.09	7.12±0.01	38.58±2.05	38.53±1.62	1.8±0.19
GA+straw	92.07±0.22	84.17±0.10	9.69±0.10	7.90±0.13	32.46±0.98	38.91±0.44	3.7±0.21
CP+straw	91.38±1.23	83.60±0.65	9.23±0.03	7.78±0.59	35.73±1.46	41.63±0.48	102.8±1.70

CT: condensed tannin, ND: Not determined, The CT reported in this table represents CT in only the browse plants and not browse plants and straw.

Table 2 Total gas, gas composition and ammonia nitrogen of treatments

Diet	Total gas (ml/gDM)	Methane (ml/gDM)	Co_2 (ml/gDM)	H_2 (ml/gDM)	NH_3N (mg/l)
SS	37.33	5.38 (14.4)	16.19 (43.4)	0.06	75.00
SeS+straw	30.33	4.34 (14.3)	15.48 (51.0)	0.08	77.85
GA+straw	33.17	4.37 (13.1)	15.86 (47.8)	0.06	74.72
CP+straw	28.83	3.34 (11.6)	11.74 (40.7)	0.05	75.47
P.value	0.88	0.63	0.86	0.79	0.952
Std. Error	7.94	1.08	4.15	0.02	0.114

SS: Sole straw, SeS+Straw: *Senna siamen*, GA+Straw: *Gmelina arborea*, CP+straw: *Ceiba pentandra*; Figures in parenthesis are a percentage of the total gas accounted for by methane and carbon dioxide

buffer consisted of 9.8g/l $NaHCO_3$, 2.77g/l Na_2HPO_4 0.47g/l NaCl, 0.57g/l KCl, 0.04g/l $CaCl_2$, 0.06g/l $MgCl_2$. The rumen fluid and buffer was mixed in a proportion of 57% and 43% respectively. Approximately 15g of test diet was fed at 12 hours interval with buffer continuously pumped into the vessels containing the substrate at rate of 60ml/hrs. The vessels were fitted with gas collection bags to collect the total gas produced and the composition of the gas analysed using the portable biogas analyser (PGD3-IR).

The data was analysed using ANOVA from Genstat 12.1 (2006). The results are presented in tables.

Results and Discussion

In vitro gas production (IVGP) gives an indication of the extent to which the carbohydrate of the substrate is being fermented by anaerobic microbes in the rumen (France *et al*., 2000). The total gas produced from CP+straw is about 23% lower than the gas produced from SS and the methane gas was also 38% lower. The result shows that the combination of CP and straw reduced both digestibility and methane production. *Ceiba pentandra* contains a CT of 102.8g/kg (**Table 1**) and this might account for the reduction in total gas production and methane gas production. The reduction in methane might be attributed to the inhibition of the two main bacteria (*Ruminococcus flavefasciencs* and *Ruminococcus albus*) in the rumen responsible for production of hydrogen which serves as a primary raw material for methanogenic bacteria to produce methane (Van Gylswyk, 1995). The replacement of straw with 40% CP, GA and CS resulted in 38%, 19% and 19% respectively, reduction in methane production. This result agrees with Hariadi and Santoso (2010) who observed a decrease in IVGP and methane production when *Pennisetum purpureum* was supplemented with *Acacia mangium* which contained total tannin of 54g/kg. Condensed tannin has been reported to directly inhibit microbial attachment to the cell wall of plants in the rumen there by reducing the digestibility of the browse plants (Bae *et al*., 1993). Condensed tannins also reduced methane production through a reduction in fibre digestion, which decreases the amount of H_2 production and also by directly inhibiting the growth of methanogens (Tavendale *et al*., 2005). Percentage of methane produced per gram dry matter was 14.4% for SS compared with 11.6% for CP+straw. This means more energy was lost to methane production in SS compared to CP+SS.

Conclusion and recommendation

The results indicate that replacing straw with 40% browse plants reduced methane production by 19-39% with *Ceiba pentandra* resulting in the highest reduction.

Further study is recommended to investigate the effect of these browse plants on *Ruminococcus flavefasciencs* and *Ruminococcus albus* since they are responsible for hydrogen production in the rumen.

Acknowledgement

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E9

Evaluating yield response of paddy rice to irrigation with application of the aquacrop model in northern region of Ghana

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Abstract

Yield of lowland paddy rice (Oryza sativa L.) is sensitive to water application regimes, which can be affected by irrigation management. The objective of this study was to analyse the response of rice yield to different irrigation water application regimes of rice grown both at On-Station and On-Farm in dry season by using the AquaCrop model. The experiments were conducted in 2012 at On-Station and 2013 at On-Farm with five treatments (continuous flooding vs. field capacity moisture content, saturation soil condition, 10 ETc and 15 ETc). The model was calibrated in terms of green canopy cover, aboveground dry biomass, harvest index and paddy rice yield. The validation of the model using efficiency criteria ((R^2), RMSE, RMSE-observations standard deviation ratio (RSR), Index of agreement (d) and Nash-Sutcliffe Efficiency (NSE)) showed satisfactory simulation results for biomass, harvest index, yield and green canopy cover. The AquaCrop model proved to be robust and applicable for paddy rice under various irrigation regimes, although it underestimates the dry biomass and grain yield for all the other irrigation methods except for field capacity. The simulated rice yield was highly sensitive to the maximum canopy cover. Because the AquaCrop model was applied to the paddy rice crop for the first time in Northern Ghana and this research was site-specific, the model need to be further tested with different climate conditions, soil types, and other rice varieties in Ghana.

Introduction

Agriculture is the largest consumer of water, on the average 80 % of water consumption in developing countries (Gately, 1995). Overuse of water can lead to the depletion of surface and groundwater resources, causing water shortages (Merla, 1998). Increasing water scarcity call for the need to optimise its use in all human activities, particularly in irrigation, the main water use sector worldwide. Irrigation currently uses more water than all other users and agriculture faces competing demands for water from other sectors (Toung and Bouman, 2002). Estimating attainable yield under water-limiting conditions will remain central in arid, semi-arid and drought-prone environments.

To address this need, FAO has developed a yield-response to water model. AquaCrop is a crop water productivity simulation model for estimating yield response of field crops (cereals, roots and tubers and legumes), vegetables and tree crops to water. The research therefore analysed the response of rice yield to different irrigation water application regimes for rice grown both at On-Station and On-Farm in dry season by using the AquaCrop model.

Materials and Methods

Study site description and experimental design

The study area comprised On-Station research at the Savanna Agricultural Research Institute (SARI) in Tolon District and On-Farm research at Bontanga Irrigation Scheme at Kumbungu District, both in the Northern Region of Ghana. The two districts together used to be one district called the

Tolon-Kumbungu District, which lies between latitudes 9° 15′ and 10° 02′ N and Longitudes 0° 53′ and 1° 25′ W.

The experiments were laid out in *randomized complete block design* with four replicates. The treatments were distributed randomly and independently in each block using draw lots method. The variety of rice that was used for the experiments was "*Gbewaa*", the "Jasmine 85" (115 days). Nursing of seeds was done at SARI for both On-Station and On-Farm experiments at 2012/2013 and 2013/2014 dry seasons. Transplanting was done manually at a spacing of 20 cm × 20 cm and one seedling per stand. Plot size was 1 m x 1 m for the On-Station experiments and 1m x 7 m for the On-Farm experiments. Data from dry season's On-Station experiments and On-Farm experiment were collected using five (5) treatments comprising of the following:

Surface irrigation with applied water equal to the: Field Capacity (FC) moisture content of the soil, (W_1); the Saturation soil moisture content (SC), (W_2); Continuous flooding up to 10 cm to be used as **control** (W_3); 10 ETc, (W_4) and 15 ETc, (W_5). All treatments were replicated four (4) times.

Aquacrop Model Calibration and Validation

The model was calibrated using data of the first production year obtained from the On-Station experiment in 2012/2013. The calibration was done using parameters such as: harvest index, canopy cover at maximum tiller, grain yield and total above ground biomass during the growing period. Other information used was soil profile and texture and climatic (daily and monthly) data from Tamale synoptic station and SARI climate station, field management practices and irrigation regimes and schedule. The recommended values provided for the rice crop parameters were also used for the calibration/validation exercises of the AquaCrop model with experimental data. The model performance was evaluated using goodness-of-fit statistics such as the Nash-Sutcliffe model efficiency (NSE) by Nash and Sutcliffe (1970), the Pearson's coefficient of determination (R^2), the index of agreement (d) by Willmot (1981), Root Mean Square Error (RMSE) and RMSE-observations standard deviation ratio (RSR) the On-Farm experiment in 2013/2014.

Results and Discussion

Relationship between Observed and Simulated Grain Yield, Biomass, Harvest Index and Maximum Canopy Cover for the On-Station and On-Farm Experiment

The relative errors of simulated grain yield and biomass were between -0.31% to 6.51% and -12% to 6.74%, respectively for On-station. However, with respect to On-farm, the relative errors of simulated grain yield and biomass were between -4.814 % to 1.078 % and -0.720 % to 4.668 %, respectively. These showed an agreement between the simulated and observed above ground biomass and grain yield. The relative errors of simulated harvest index was from -0.56% to 5.64% for On-Station. The model has not only slightly over-estimated HI for W2, W3 and W4, but also under-estimated HI for W1 (5.6) with W5 given exact value for both simulated and observed HI (0). However, with respect to On-Farm, the relative errors of simulated HI was between 0.688 % and 10.03 %. Accordingly, the results of these studies show that the AquaCrop model is capable of simulating harvest index. However, the relative errors of simulated canopy cover were between 5.02 and 9.49% for On-Station. However, with respect to On-Farm, the relative errors of simulated CC was between -0.161 to 2.258 %. Accordingly, the results of these studies show that the Aquacrop model is capable of simulating canopy cover, but with slight difficulties as compared to the other parameters.

Validation of Aquacrop Model Using On-Station and On-Farm Experiment Results

The results of index of agreement (d) and coefficient of determination $\mathbf{r^2}$ for grain yield, biomass, harvest index and canopy cover simulations for different irrigation treatments were obtained between 0.523 and 0.986 for **d** and 0.81 to 0.99 for $\mathbf{r^2}$ in 2012/2013 and between 0.806 and 0.995 for **d** and 0.938 and 0.999 for $\mathbf{r^2}$ in 2013/2014 for On-Station and On-Farm respectively with canopy cover giving the lowest value, while grain yield gave the highest value for the two study areas. This therefore suggests that the ranges of values for the various parameters were within acceptable limits. With respect to Nash-Sutcliffe efficiency (NSE), the simulations for different irrigation treatments were between -4.642 and 0.859 for the various parameters under investigation for On-Station while that of On-Farm ranged between -0.87 and 0.984. Canopy covers ones again yielded the lowest value of efficiency while grain yield gave the highest value. This implies that the model performance for canopy cover is not acceptable. Also, the ranges of RMSE and RSR in these simulations for different irrigation treatments were from 0.085 to 5.899 and from 0.375 to 5.643 respectively for On-station experiment. In the case of On-farm experiment, the ranges are from 0.127 to 1.687 for RMSE and between 0.126 and 1.87 for RSR. This therefore indicates that the AquaCrop model has a good simulation for all the parameters. The values of RMSE showed a better simulation for the grain yield (0.435 t/ha) and (0.127t/ha) than the biomass (1.106 t/ha) and 0.364 t/ha.

Conclusion

The AquaCrop software was able to simulate well the canopy cover, harvest index, biomass and yield of rice. The validation of the model using efficiency criteria ((R^2)**,** RMSE, RMSE-observations standard deviation ratio (RSR), Index of agreement (d) and Nash-Sutcliffe efficiency (NSE)) showed satisfactory simulation results for biomass, harvest index, yield and. The AquaCrop model proved to be robust and applicable for paddy rice under various irrigation regimes. Therefore, this model can be used as a decision support tool in increasing water productivity by project managers, consultants, irrigation engineers and farmers.

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E10

Farmers' livelihoods and welfare impacts in Wa West district, Upper West region of Ghana

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Introduction

The ultimate aim of governments and their development partners is to increase the welfare of the people. This is especially so in drought and flood-prone farming communities in the northern part of Ghana. Ghana is a middle income country but the nation has a lot of developmental challenges, especially in recent years of global economic downturn and climate variability. While the nation as a whole is at the lower middle income level, economic challenges in the northern part are even more precarious. The Wa West District is no exception. Over the years though, the district has had a fair share of the development programmes and projects in the region, all aimed at diversifying the sources of livelihood of the people. However, it would not be true to say that all the members of the communities have equal access to these opportunities, neither can one jump into conclusion, without an empirical study, that the number of income generating activities necessarily translates into increased welfare. It is against this backdrop that a study to investigate the determinants of livelihood activities and its effects on participants' welfare is necessary.

Objectives

The main objective of the study was to investigate the socio-economic determinants of farmers' engagements in livelihoods (L) and its effects on their welfare (W).

Materials and Methods

The objective of the study implies an estimation of L equation with W as one of the explanatory variables. However, W itself may be determined by L also, which means that both L and W are both endogenous. Thus, there is simultaneity between the two variables. In this case, an estimation of a single equation by the Ordinary Least Squares (OLS) would result in simultaneous equation bias ,which means that we are not able to measure the true effects of L on W and vice versa. The appropriate method is the Two Stage Least Squares (2SLS) (Koutsoyiannis, 1977).

A multi-stage sampling technique was employed to select a total of 184 farmers from four communities in the Wa West District, which is located in the western part of the Upper West Region of Ghana. The four communities, Baleufili, Bankpama, Chietanga, and Zowayeli, were selected through comprehensive selection processes, based on agro-ecological, engineering, and socio-economic resilience/vulnerabilities under a project titled "Enhancing Resilience to Climate and Ecosystem Changes in Semi-Arid Africa: An Integrated Approach (CECAR-Africa)" in 2012.

Eighteen socioeconomic activities were identified including crop farming, livestock rearing, poultry keeping, shea butter processing, *pito* (local beer) brewing, charcoal making, fishing and trading. Welfare indicators included farmers' cash and food security, affordability of health care and renovation of houses as well as level of happiness.

The survey adopted semi-structured individual interviews, which were conducted in local languages (Waale, Dagaati, and Brifori). Visual observations of some socio-economic characteristics, such as housing type, clothing, livelihood assets, nutritional status of family members, and reactions of interviewees to various questions, were also made throughout the interviews.

The empirical model of the study is as follows:

$$L = \alpha_0 + \alpha_1 Age + \alpha_2 Sex + \alpha_3 Education + \alpha_4 Household\ size + \alpha_5 Welfare + u_1$$

(Livelihood)

$$W = \beta_0 + \beta_1 Age + \beta_2 Sex + \beta_3 Education + \beta_4 Household\ size + \beta_5 Farmsize + \beta_6 Livelihood + u_1$$

(Welfare)

Table 1: Maximum Likelihood Estimation of the Livelihood function

Variable	Coefficient	Standard error	T-Value	P-Value
Age	-1.4919***	0.0430	-34.73	0.000
Sex	-0.7668***	0.0221	-34.72	0.000
Education	-1.1891***	0.0324	-36.74	0.000
Household size	0.8474***	0.0259	32.71	0.000
Welfare	47.7423***	1.1990	39.82	0.000
Constant	-59.9809***	1.5196	-39.47	0.000

*** Significant at 1%

Table 2: Maximum Likelihood Estimation of the Welfare function

Variable	Coefficient	Standard error	T-Value	P-Value
Age	0.6059***	0.0204	29.77	0.000
Sex	-0.6015***	0.0182	-33.03	0.000
Education	-0.1311****	0.0074	-17.73	0.000
Household size	-0.0105***	0.0004	-24.21	0.000
Farm size	0.0022	0.0038	0.56	0.576
Livelihood activities	9.8222***	0.2832	34.68	0.000
Constant	-3.8929***	0.1496	-26.02	0.000

*** Significant at 1%

Results and Discussion

From the estimation results in **Tables 1** and **2**, all the variables, except farm size, were significant, most of them maintaining their expected signs. The factors that negatively influenced the number of Ls of farmers were age, sex and education. Household size and welfare however, had positive effects on L. This means that the number of L was high for the following category of farmers: relatively young farmers; females; farmers with little or no formal education, farmers with larger families and richer farmers. Similarly, the factors that negatively influenced W were sex, education and household size. The positive determinants of W were age and L. This also implies that W was higher for the following categories: older farmers; female farmers, farmers with little or no education, farmers with smaller family size and farmers with a number of Ls.

Conclusion

Putting the two results together, we can conclude that even though younger farmers and farmers with big family size had engaged in more Ls, this did not translate into increasing their welfare. These categories of farmers must be targeted for policy formulation. In general, however, we recommend the promotion of more Ls so us to increase the welfare of farmers.

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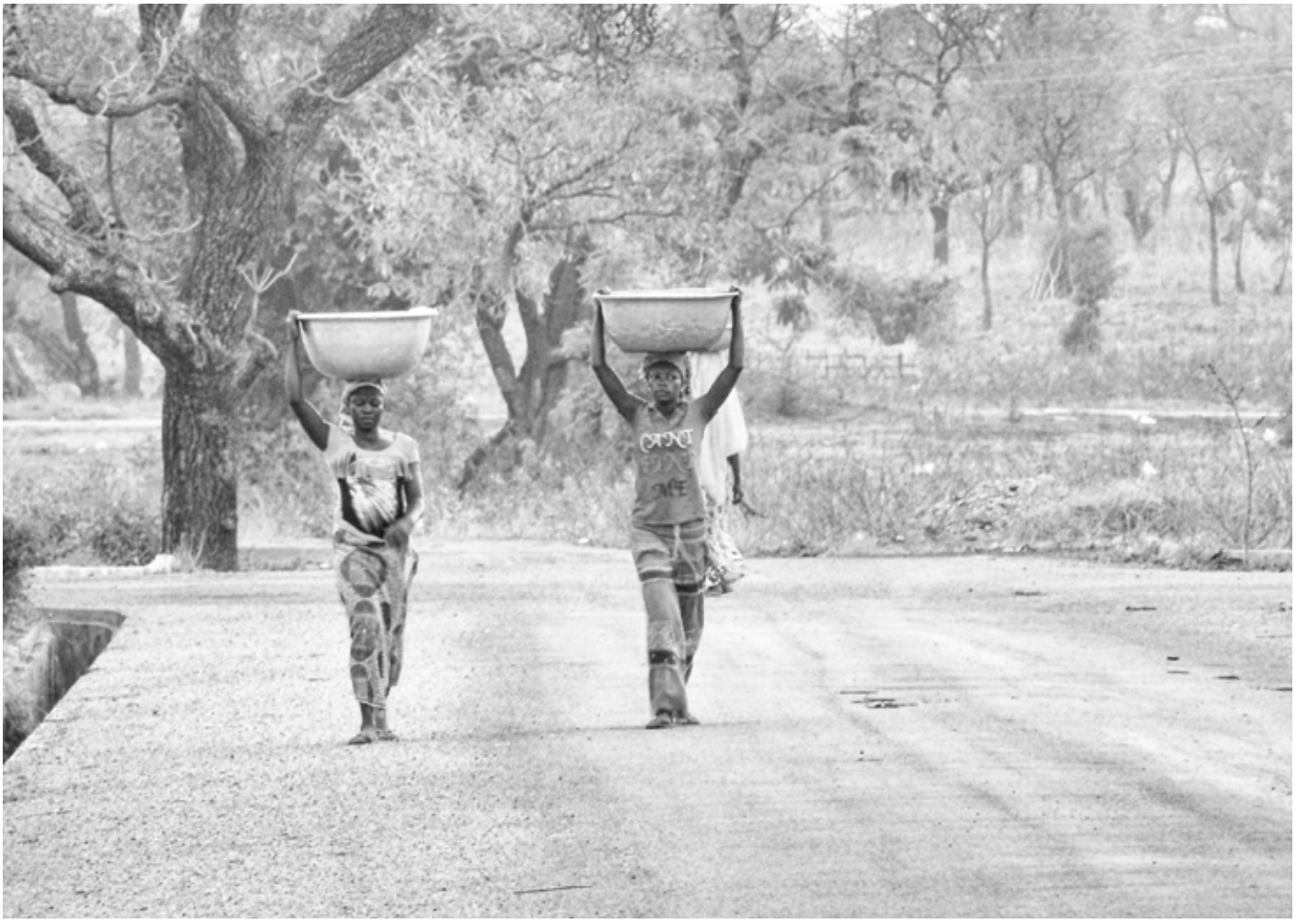

Thursday 7th August 2014

13:30 – 17:00

ABSTRACTS

SESSION F

F1 » 10

Capacity Assessment and Resilience Enhancement

F1

Studies of resilience efforts by farmers in northern Ghana: indigenous tillage practices used to reduce to the effect of rainfall and temperature variation

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Abstract

Traditional knowledge and practices of indigenous people have, over the years, played a significant part in solving their livelihood problems. These practices may be used in addressing challenges related to climate variability. Indigenous people live close to natural resources and often observe the activities around them and are able to identify and adapt to changes. Indigenous people have frequently used biodiversity as a buffer against variation, change and/or catastrophes; if one crop fails, another will survive. In coping with risk due to excessive or low rainfall, drought and crop failure, some traditional practices have been used for a very long time, such as mixed cropping (crops of different varieties and susceptibility to drought and/or floods). The diversity of crops and food resources is often matched by a similar diversity in location of fields, as a safety measure to ensure that in the face of extreme weather, some fields will survive to produce harvestable crops.

Adaptation to climate variation also includes adjustments in behaviour or economic structure that reduce the vulnerability of local society to changes in the climate system. Whether people can adapt, and for how long, also depends on the resources available to them. Northern Ghana is vulnerable to the negative impacts of climate variation and at the same time has low adaptive capacity due to the people's general poverty. But the people, particularly at the local level, are making efforts to adjust to the changes they observe.

Tillage practices used in Northern Ghana are generally ploughing or ridging using tractor or bullocks, mounds or camber beds preparation or direct planting on previously tilled lands. The type of tillage used depends on the region, ethnic group and the environment (drought or flood prone) among others.

Additional methods of land preparation practices are 'slash and burn', traditional land clearing, still used in some parts of the region, or leaving the weeds unburnt, clean clearing and zero tillage. The practice of these methods depends on the soil type, weed infestation, soil depth and its fertility level.

Climatic elements cannot be controlled; however, methods of land clearing and tillage may help reduce the effects of climatic parameters on the crop. Identifying and evaluating the methods of land clearing and tillage by farmers in Northern Ghana and their effect in reducing some climatic effects affecting crop production need to be assessed for the best practices to be modified and used widely.

F2

Mainstreaming disaster risk reduction (DRR) strategies in school curricula in Ghana: an exploratory study

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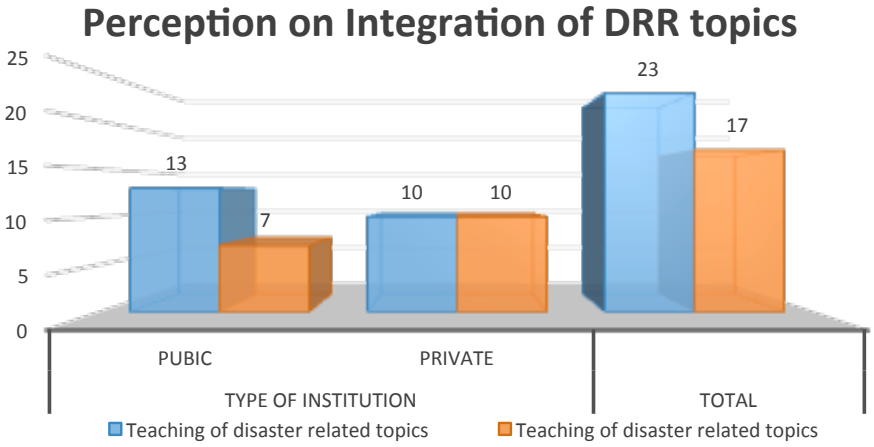
Introduction

Natural disasters are integral part of human society. They cannot be eliminated but man can only mitigate the risk in order to reduce damage and save more lives and properties. The impacts of natural disasters such as floods, volcanic eruption, earthquakes, tsunamis, droughts and wild fires on man is dependent on the level of vulnerability, exposure and ability to adapt to and recover from hazards (Brooks et. al., 2005). Contextually, vulnerability measures the degree to which a society or an individual is susceptible to a hazard (Cutter, 1996; McCarthy, 2001; Eakin & Luers, 2006; Taubenbock et. al., 2008).

In order to reduce the level of vulnerability and enhance the resilience of individuals and communities to disasters aggravated by climate change, education for disaster prevention, preparedness and management is crucial. In line with international efforts and programs aimed at addressing the complexities of disasters such as the UN International Decade for Natural Disaster Risk Reduction (1990's) and the development of the Hyogo framework, the Government of Ghana with support from various stakeholders has initiated efforts at integrating Disaster Risk Reduction (DRR) into school curricula



Source: Author's Field work, 2014

Figure 1. Perception of teachers on the level to which disaster topics have been mainstream

across the country. Taking into account that these efforts are at their early stages, concerns have been raised about the practicability and government's structural readiness. This research, thus aimed at assessing the level of mainstreaming of DRR education into pre-tertiary school curricula in Ghana from the perspective of teachers.

Materials and Methods

This research relied on primary and secondary data to draw conclusions and come out with recommendations. Primary data for this study was obtained through the use of structured questionnaire interviews with teachers from selected schools within the La Nkwantanang District of the Greater Accra Region. The studied schools comprising of two private and two public, were purposively selected with the assumption that an observable difference in responses to the level of DRR integration may exist between teachers from the two categories of schools. The schools included Presec Staff Primary and St Andrews JHS (public), St Lutheran School (private), Madina Secondary (public) and Preset School (private). Using structured questionnaires, forty teachers composing of ten from each school were purposely selected for interviewing. The questionnaires administered were categorized into four sections with the first section addressing the demographics of respondents. The next section explored the knowledge and experience of respondents of disasters and how they responded to them. The third section examined the perception of teachers on DRR in subjects taught in the schools with emphasis on their subject of teaching. It also sought to identify the time, practices and activities that goes into the teaching of topics related to DRR and the kinds of teaching and learning materials used. The last section solicited answers on possible collaborations between schools and disaster management organisations.

Informal interviews with personnel from the National Disaster Management Organisation (NADMO) and Ghana Education Service (GES) were conducted. This allowed for a first-hand knowledge of past and present actions, policies and frameworks relating to disaster risk reduction efforts in curricula development in Ghana. Secondary data for this study came from the National Disaster Management Policy for Ghana drafted in 2010 and a report (yet to be published) on the assessment of the various subjects into which DRR has been integrated was obtained from NADMO. The latter report guided the research in selecting the subject of which the respective teachers from the selected schools were contacted. The secondary data obtained from NADMO was reviewed while the primary data obtained from the questionnaires were coded and entered into IBM SPSS for further analysis.

Results and Discussion

Regarding disasters, prevention, response and management were identified by respondents as crucial in a world where climate change has worsened the impacts of disasters on human life and property. All 40 respondents emphasized on the importance of educating students on disaster issues. In acknowledging children (students) among the most vulnerable group in society especially to natural disasters, they also serve as excellent agents of communication. It was reiterated that training students on issues related to disasters, not only help in saving their lives but also that of their family and community. However, further investigation revealed that 80% of respondents had not undergone any form of training or had any form of education on disasters to equip them in the discharge of their duties to students. Also, the knowledge and exposure of respondents to the term 'Disaster Risk Reduction' showed a low trend. Out of the 40 teachers sampled from four different schools, only 45% (18) of respondents had heard of the term from the media, interactions with disaster management organizations, personal research works and as part of their studies in the tertiary institution. The other 55% (22) of respondents had not come across the term before.

Some respondents which comprise 57.5% (23 people) of respondents said topics on disasters had been mainstreamed into other subjects. By comparison, the perception of teachers within the public and private schools on the level of to which disaster topics had been integration into schools revealed that majority of teachers within the public schools agreed to this (13 of 20 respondents). On the other hand, 10 out of 20

respondents (50%) from the private schools held the opinion that topics on disasters are mainstreamed into the curriculum. **Figure 1**, show the result.

However, all 23 teachers believed the current topics on disasters were too shallow and woefully inadequate in transmitting the necessary knowledge students needed to prevent, manage and respond to disasters. One of the respondents from the primary level was noted saying:

'We only talk about the various types and forms of disaster during the period for citizenship. We don't go beyond this since issues of response and management during periods of disasters have not been included in the curriculum. We also do not have enough time and teaching materials even if we wanted to go further'

Teachers within the JHS and SHS especially those teaching English and Ghanaian language and culture stated categorically that they did not directly teach students about disasters but sometime gave them writing assignments that involved elements of disaster. They conducted no form of drills or practical sessions with students on disasters. Respondents therefore identified their lack of training together with insufficient time, inadequate teaching and learning materials on the topic, a lack of appreciation by students for issues of disasters and the not too in-depth nature of disaster topic which have been integrated into other subjects as setbacks in the process of teaching DRR topic. This study found slight variations in the subjects identified by teachers as containing disaster topics and those listed by GES in the report from NADMO. These variations may be accounted for by the seemingly limited knowledge of teachers in subjects outside their expertise. It might also be that respondents did not actually handle any disaster related topics within these subjects and thus saw no need to include them in their list. However, social studies and integrated science came up highly recommended by most respondents within the JHS and SHS level. Also, the study was unable to contact all teacher handling subjects list by the GES as having topics on disasters.

Conclusion

In an era of increased climate-induced disasters with their associated impacts on human life and property across the world, education for disaster prevention, preparedness and management has become fundamental Findings from this study however reveals that the topics on disasters are insubstantial and unable to adequately address issues of disaster prevention, response and management. Teachers suggested that topics on disaster should be made a subject on its own with textbooks and visual aids being produced and supplied solely for that purpose. They were however quick to point out that the current curriculum structure and the work load on both teachers and students, this will not be feasible and thus called on Ghana Education Service to help clean-up the syllabus.

The research thus, calls not only on government but also disaster management organizations like the National Fire and Rescue Service and NADMO to actively engage teachers in the form of training and seminars to adequately prepare them to deliver their best to students. Also, extra-curricular activities within schools could be shifted a bit toward disaster education and the various clubs teaching disasters must be strengthened and well-resourced to impart the necessary knowledge and skill of disaster prevention, management and response to students. Topics on disasters in various subjects should move toward developing a culture of prevention within students and should also focus on practical steps that can be taken by students when they are faced with any form of disaster.

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F3

Assessment of capacity building initiatives towards enhancing resilience to climate change in Ghana: the role of University education

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Abstract

Coping with global climate and ecosystem changes requires developing countries with weak socioeconomic and resource management regimes to devise adaptation strategies. Climate is usually defined as the average weather condition of a place. It includes patterns of temperature, precipitation, humidity, wind and seasons. Climate patterns play a fundamental role in shaping natural ecosystems, human economies and cultures that depend on them. But the inherited climate is not what it used to be, because the past is no longer a reliable predictor

of the future. Our climate is rapidly changing with disruptive impacts, and that change is progressing faster than any seen in the last 2,000 years. Climate Change, as a school of thought, concerns itself with these environmental dynamics. Climate Change is a significant and lasting change in the statistical distribution of weather patterns over periods ranging from decades to millions of years. Climate Change is caused by factors such as biotic processes, variations in solar radiation received by Earth, plate tectonics, and volcanic eruptions. Human activities that produce 'global warming' are a significant part of the causes. Using environmental hermeneutic approach, this paper examines the role of tertiary education, through Ghana-based universities, in building local capacity towards effective resilience and contextual adaptation.

F4

Capacity development approaches for improved resilience in rural communities: key lessons from Tolon district of northern Ghana

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Abstract
This paper presents a template for designing capacity development interventions for local communities and supporting institutions in semi–arid areas using lessons from Ghana. Using participatory approaches, the researchers worked with local community stakeholders, other NGO actors and local government authorities using qualitative tools to identify the support systems needed to help local communities improve their resilience to climate and ecosystem changes. At the institutional level, key officials of the District Assembly such as the Chief Executive, the District Planning Officer, District Directors of Agriculture, Health and Education amongst others were purposively sampled for the conduct of a face to face interview using unstructured questionnaires. At the community level, three separate groups of young men, women and elders/ traditional leaders were formed for separate focus group discussion sessions using a structured question guide in Zagua and Kpalgun of Tolon District. The findings from the institutions show the anticipatory as well as usual practice of discharging statutory obligations to the local communities. Standard response mechanisms to vulnerable situations had constraints of weak actor synergy and resource quality and timely availability. The communities tend to know development intervention profile of actors they have worked with and remember most, those that have left concrete out puts such as boreholes, extension service, disaster relief and market links amongst others. This paper structures the key lessons from each group of respondents into a working template for enhancing resilience to climate change related capacity development support from NGOs, Research Institutions and other Development Partners.

Keywords: *Capacity development, Resilience, Community, Northern Ghana*

F5

Enhancing sustainable development for rural communities in semi-arid regions of Ghana – evidence from Baleufili in Wa West District

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Abstract
The paper uses the Sustainable Livelihoods framework as an analytical tool to present interplay of context, a set of innovative community activities and institutional support systems that can inform sustainable interventions to help development of rural communities facing threats of climate variability. Community Resource Mapping was undertaken as well as an inventory for community institutions contribution to development. Face to face interviews were carried out

for 125 men, women and youth using a three generational approach on detailed livelihood activities they were engaged in. Focus group sessions were also held to confirm the findings from the interviews. The results show that good road network, irrigation infrastructure with appropriate water facility user education and market based production of agricultural commodities with good market linkages can enhance ecological as well as socio-economic resilience of such communities for enhanced sustainable development. The paper recommends appropriate supporting infrastructure, development of good social capital and market linkages as good triggers for sustainable development.

Keywords; *Sustainable livelihoods, Semi-arid Ghana, interventions, education, resilience*

1.0 Introduction

The paper uses the Sustainable Livelihoods Framework as an analytical tool to present interplay of context, a set of innovative community activities and institutional support systems that can inform interventions to help sustainable development of rural communities facing threats of climate variability. Community Resource Mapping was done as well as an inventory for community institutions contribution to development. Interviews were carried out for 125 men, women and youth using a three generational approach on their livelihood activities. Focus group sessions were also held to validate the findings from the interviews. The results show that good road network, irrigation infrastructure with appropriate water facility user education and market based production of agricultural commodities with good market linkages were necessary to enhance ecological and socio-economic resilience of such communities for enhanced sustainable development.

According to Chambers and Conway (1992), "a livelihood comprises the capabilities, assets (including both material and social resources) and activities required for a means of living. A livelihood is sustainable when it can cope with and recover from stresses and shocks; maintain or enhance its capabilities and assets, while not undermining the natural resource base" Chambers and Conway (1992).

In establishing the criteria for socio-economic and ecological resilience, such factors as resistance to the impacts of climate variations as evidenced in high incidence and severe flooding of the Black Volta in the high tide season, high incidence of extreme drought conditions in the farming season, annual flooding due to torrential rains, recurrent bushfires, decreasing soil quality, deteriorating vegetative quality, and attendant low crop yields leading to perennial hunger, poverty, deprivation, and a perception of general hopelessness that triggers rural-urban migration and a myriad of other challenges were considered. Resilience therefore meant that a community was still viable after the occurrence of these climate change related disasters, and the reverse is true for Less Resilient/Vulnerable communities. From this background, Baleufili was classified as Resilient, meaning that the community had a set of innovative activities and institutional support systems that enabled them remain resilient in the context of these impacts. This paper investigated how these systems can inform sustainable interventions to help development of rural communities facing threats of climate variability.

2.0 Materials and Methods

2.1 Study Area

The Baleufili community is located in the Wa West District of the Upper West Region of Ghana. The community is located within the Semi-arid zone of Ghana. This community is located along the southern bank of the Black Volta River along with other communities as Chiatanga, Bankpama, and Zowayeli. The CECAR Project selected four communities in the Wa West district based on community socio-economic and ecological resilience criteria as Resilient or Less Resilient/Vulnerable. Two of the selected communities namely Baleufili and Chiatanga were classified as Resilient while the other two Bankpama and Zowayeli were classified as Less Resilient/Vulnerable. Baleufili is a mainly agrarian community, made up of Waala, Dagaaba, and Birifo ethnic groups. The community faces challenges arising from the impact of climatic variations. Such challenges include delayed and reduced rainfall, perennial and prolonged spells of drought, flooding along the river bank destroying agricultural production, bushfires, depleting vegetation, severe storms, and low soil fertility among others. The impacts of these challenges of climate changes have taken a heavy toll on agricultural production which is the main source of livelihood in the community. The community within the context of these challenges has adopted a set of innovative community activities and institutional support systems that can inform sustainable interventions to help development of rural communities facing threats of climate variability.

2.2 Analytical Framework

The Sustainable Livelihoods Framework (SLF) is used as an analytical tool to present the interplay of context, a set of innovative community activities and institutional support systems that can inform sustainable interventions to help development of rural communities facing threats of climate variability. The SLF depicts actors in a **Context of Vulnerability**, within which they have access to certain **Assets**. These gain their meaning and value through the prevailing social, institutional and organizational environment **(Transforming Structures and Processes)**. This context decisively influences the **Livelihood Strategies** that are open to actors in pursuit of their self-defined beneficial **Livelihood Outcomes**. The framework provides a checklist of important issues and details how these link to each other, while it draws special attention to core influences and processes and their multiple interactions in relation to livelihoods.

2.3 Methods

As part of methods, Community Resource Mapping was done as well as an inventory for community institutions and their contribution to development. Both primary and secondary data were used in this research. Interviews were conducted for 125

men, women and youth using a three generational approach on their livelihood activities. Focus group sessions were also held to validate the interviews results.

3.0 Results/Discussions

It was found that the community had a man-made dam with a functional but limited irrigation system that has helped community members to engage in dry season farming to supplement the unreliable and erratic rain fed agriculture. The community has also demarcated the land around the dam such that interested community members are entitled to a quarter of an acre of irrigated land for crop production. Some community members who are beneficiaries of the farming land around the dam have also fenced the land using mud brick walls, gardens, and a specie of cactus flowers (milk flowers) to fend off grazing livestock from their crops. Besides this, the dam has also supplemented the water supply needs of the community for domestic water uses and also livestock production. Furthermore, the area around the dam has green vegetation all year round, so the community also grazes their livestock around the dam area. The results indicated that seasonal hunger, low crop yields, poor storage systems, poor market access, poor quality road networks, and weaker transport systems, were some of the challenges to livelihood systems of the area. The evidence show that *good road network*, *irrigation infrastructure* with appropriate *water facility user education* and *market based production of agricultural commodities* with *good market linkages* can enhance ecological and socio-economic resilience of the community for enhanced sustainable development.

4.0 Conclusion

The community is facing challenges as a result of climatic variations, and these have resulted in poor agricultural production and resultant hunger, poverty, deprivation and a sense of hopelessness. That notwithstanding, the community has managed to stay viable and continue to maintain a livelihood in agricultural production using these innovative community activities and institutional support systems. Taking from the evidence presented, the paper concluded that good road network; functional irrigation infrastructure with appropriate water facility user education and market based production of agricultural commodities with good market linkages can enhance community socio-economic as well as agro-ecological resilience. Finally, the paper advocated that appropriate supporting infrastructure, development of good social capital and market linkages were good triggers for sustainable development.

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F6

Capacity assessment framework, processes and indicators: lessons from a sustainable rural livelihoods project in northern Ghana

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Local capacity has been increasingly addressed in various development interventions as a critical driver in the last decades, partially because local capacity is believed to contribute to enhancing people's wellbeing in a longer term. However, many projects tend to fail to identify specific areas of capacity which need to be developed and/or how such core capacities can be developed, resulting in minimal capacity outcomes. In order to overcome such challenges and contribute to sustainable outcomes in both capacity and wellbeing, UNDP and Africa 2000 Network-Ghana implemented the Sustainable Rural Livelihoods Project (SRLP) in Northern Ghana from 2006 to 2011. This project facilitated a Capacity Assessment of key local stakeholders and undertook strategic capacity development activities, which resulted in enhanced capacity and sustainable development outcomes. The SRLP conducted a series of local stakeholders' dialogues which led to identification core capacities for sustainable rural livelihoods in the context of Northern Ghana, i.e., 1) leadership, 2) engagement, 3) mutual accountability, 4) asset management and entrepreneurship, and 5) vulnerability management; and these can be further analyzed and adopted in various capacity development interventions. Against this backdrop, this study examines the capacity assessment framework and processes initiated by the SRLP in order to provide constructive implications and feasible measures, which could possibly be adopted by ongoing and future capacity development interventions. Data collection methods employed for this study include interviews of key project members, observations and review of project documents and other relevant literatures. Specific objectives of this study are: 1) to analyze the framework and processes of a capacity

assessment initiative; 2) to examine core capacities and relevant indicators identified and adopted by key stakeholders; and 3) to explore feasible and sustainable approaches for capacity development in the context of Northern Ghana and beyond.

Keywords: *Capacity, Capacity Assessment, Livelihoods, Sustainability, Northern Ghana*

F7

An assessment of the knowledge, attitudes and practices among organizations on climate change in Tolon and Wa West districts, northern Ghana

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Abstract

This study explored the knowledge, attitudes and practices (KAP) of organizations operating within two Districts of Northern and Upper West Region of Ghana. It identified the gaps within the KAP framework for capacity building. Climate change places a huge demand on existing governance institutions to strategize and work more effectively to enhance the resilience of vulnerable societies. Due to their long-term socio-economic implications and potential adverse effects on the everyday lives of people, adverse extreme weather events such as changes in average temperature, rainfall, increased frequency of extreme events such as floods, droughts, and rainstorms have become a major concern for most households in Tolon and Wa West Districts of Northern Ghana. The role of organizations and institutions in informing and educating the public on climate change related issues as a means to lessen vulnerability is therefore paramount. However, existing organizations cannot effectively play such a role unless they are by themselves adequately prepared in terms of knowledge, attitudes and practices of responding to the adverse effects of climate change. Interviews were conducted using a semi-structured questionnaire with a purposively selected sample of staff of all relevant stakeholders and organizations in each district. An intervention model is proposed for adoption in support of programmes to build resilience in local communities' preparedness against extreme weather events in similar contexts to inform policy recommendation.

Keywords: *climate change, organizations, knowledge, attitude and practices*

F8

Agronomic and marketing innovation enhances vegetable farmers' resilience

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Abstract

Resilience is the ability to absorb shocks without an entire system change. Farmers develop adaption mechanisms that enhance their resilience to sudden changes that occur in their dynamic environment.

We describe some examples of farmers' practice that illustrate how they have developed resilience to climate variability. We focus on vegetable farmers in Tamale, Northern Ghana. We see ability to manipulate markets as part of the range of strategies they use to circumvent vulnerability to climatic fluctuations. We therefore describe the tactics they implement not only in the agronomic but also the marketing spheres.

Water is limited in Northern Ghana. Farmers innovate to reduce the risks associated with this. They grow crops in areas where soil residual moisture is high. Ridging and mulching help maintain soil water levels. Cultivation of hardy crops, such as okra and ayoyo, into the dry season can also be invoked as a risk reduction strategy.

Mixed cropping allows farmers to manipulate what they offer to market traders. This lets them respond to seasonal fluctuations in price in order to optimise their income flows.

They also develop social networks to maximize their ability to use markets to their advantage. This is important in situations where they have less ability to predict agroecological conditions. They engage multiple marketers, whilst strengthening relationships with those who are particularly reliable. This helps them guarantee a buyer when demand is low, of especial importance when variable climatic conditions produce market gluts.

By enhancing both agronomic and social heterogeneity, these innovations address the risks associated with climatic variation. We conclude that such diversification is one very effective way that farmers develop their resilience to such change.

F9

Determinants of climate change adaptation strategies by smallholder farmers in east Mamprusi district of northern region, Ghana

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Abstract

Climate variability and change have become a global phenomenon that continues to affect the very survival of man, especially those whose livelihoods depend so much on rain-fed agriculture. Included in this category of vulnerable people are smallholder farmers who rely mainly on crop production. Coping strategies adopted by smallholder farmers in the past are increasingly becoming unworkable as the impacts of climate change and variability intensify. In the face of increasing vulnerability smallholder farmers have resorted to adaptation strategies that are helping them to survive the impacts and farmers in the East Mamprusi District of the Northern Region of Ghana are no exception. The study aims at determining the factors that influence farmers' choice of adaptation options. The study was carried out in the East Mamprusi District of the Northern Region of Ghana. 250 farmers (male and female) were selected from 25 communities (10 farmers per community) in 5 Area Councils, namely Gambaga, Langbinsi, Nalerigu, Gbintiri and Sakogu. Semi-structured questionnaire was used to collect data. Data analysis is ongoing using means and standard deviations, frequencies and percentages and multinomial logit regression model.

Keywords: *Climate Variability, Adaptation strategies, Smallholder farmers, perceptions, Multinomial logit model, East Mamprusi District.*

F10

Disability, climate change and human security. Policy implications for Ghana

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Abstract

The social effects of climate change have gained global prominence in recent times. The product of climate change is severe drought, floods, storms, hurricanes etc which consistently and seriously pose as threats to livelihoods and general wellbeing in developing countries like Ghana. Climate change can have direct and indirect effects especially on the poor, excluded and vulnerable including people with disability (PWD), women, children and the aged, particularly for their health. In Ghana, PWD face unequal access to education, healthcare, employment, assets and opportunities for social and community participation. However, the particular consequences of climate change for PWD and its implications on policy have been widely neglected in research so far. This PhD research is therefore an academic response to the issue of disability, climate change and human security in Ghana. It seeks to provide a comprehensive analysis of the underpinning issues within the Human Security framework using the Talensi and Nabdam districts of the Upper East Region as case study. The overarching goal of the study is to highlight challenges and propose cogent policy alternatives into the design of sustainable solutions to improve the lives of people with disabilities in Ghana. The study is designed to answer the following key questions; How are PWD affected by climate change? How do PWD adapt to climate change? How state and non-state institutions assist and respond to PWD affected by climate change? How relevant and applicable is the human security framework to PWD? How can policy be influenced in favour of PWD affected by climate change in Ghana?

A mix of qualitative and quantitative methods will be adopted to operationlise the objectives of the study. Both Primary and Secondary data sources will be relied.

ABSTRACTS

Poster Presentation

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P1

Urban and peri-urban agriculture and its implications on agroecosystem resilience, food and nutrition security

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Abstract

Global food and nutrition insecurity continues to be a serious problem, threatening the livelihoods of millions of poor people, with sub-Saharan Africa worst affected. A total of 842 million people in 2011–13, were estimated to be suffering from chronic hunger, regularly not getting enough food to conduct an active life. Food and nutrition insecurity has traditionally been looked at as a problem of rural areas. Accordingly much of the policy issues have been targeting rural populations. However, increasingly research findings are showing that urban populations can also be highly affected. Food and nutrition insecurity accompanied by climate change and rapid urban growth poses a serious challenge to many livelihoods. This leads urban dwellers to engage in farming activities to help satisfy their food needs. The percentage of urban residents in sub-Sahara Africa is expected to rise from 30 to 47 percent of the total population until 2030, further increasing urban food demand. Urban agriculture thereby has the potential to address the scourge of food and nutrition insecurity in urban and periurban areas at the same time increasing crop biodiversity and contributing to stable agroecosystems. We hypothesise that urban development and the increase in urban agricultural production can positively contribute to crop diversity, agroecosystem resilience and urban food security. Preliminary results of an on-going study conducted in Tamale on Food and Nutrition Insecurity Risk Mapping along the urban – rural continuum reveals that most households involved in urban agriculture have a higher Women Dietary Diversity Score, a proxy of better nutrition security and lower Household Food Insecurity Access Scale, a proxy of better food security. Year-round supply with urban waste water and organic manure make urban farming particularly interesting in a region where farming activities are largely restricted during the dry season and are increasingly affected by chancing seasonal weather fluctuations.

Keywords: *Urban and periurban agriculture, food and nutrition insecurity, agroecosystem resilience, crop biodiversity*

P2

Local knowledge and the causes of climate change: local perspectives and the policy implications for building community resilience in North-Western Ghana

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Abstract

Drawing on the local knowledge systems of the Sissala people of north-western Ghana, this paper analyses local perspectives of the causes of climate change and the policy implications for building community resilience in the context of rain fed agriculture.

The paper draws on a qualitative research design and methods of data collection. Qualitative methods of data collection, specifically, in-depth interviews and focus group discussions and change mapping and analysis were employed in data collection and analysis for understanding local perspectives of the causes of climate change.

From the perspectives of the local farmers, climate change is caused by multiple factors, namely, an increasing trend in the felling of trees, bush burning and over grazing, excessive use of agro-chemicals in agriculture, use of modern farm implements and equipment's, such as tractors and bullock ploughs, break down in traditional values and norms for bio-diversity conservation and spirituality, particularly, irregular worships and sacrifices of traditional gods – community, land, water and rain gods.

Literature on how local people perceive and cope with adverse effects of climate change points to the fact that they draw on their indigenous knowledge systems to observe, interpret

and respond to the consequences of climate variability and change in diverse ways (Egeru, 2012; Green and Raygorodetsky, 2010; Salick and Byg, 2007). These knowledge systems and the observations, interpretations, predictions and reactions to climate change may vary and/or have similarities from and among communities based on their economic and socio-cultural backgrounds (Roncoli et al, 2009). Nonetheless, such understanding of local perspectives of the causes of climate change is important for policy planning and the promotion of sustainable climate change adaptation interventions. The paper underscores that local perspectives on the causes of climate change largely corroborates the anthropogenic causes of climate change and that the exception is the attribution to a breakdown in spirituality – this unique attribution arising from the holistic Worldview and cosmovision of the people. This corroborates other findings that aside the natural and anthropogenic causes of climate change, indigenous people attribute its cause in part to spirituality and curses from the gods and their ancestors (Awen-Naam, 2011; Egeru, 2012; Gyampoh and Asante, 2011; Salick and Byg, 2007).

To enhance sustainable community resilience, this paper advocates a composite approach to Climate Change Adaptation Planning (CCAP) that builds on the Worldview of the people and emphasizes both mitigation and adaptation within the context of two policy frameworks – Decentralization and local governance through District Development Planning (DDP) and the National Climate Change Adaptation Policy Framework.

Keywords/descriptors: *Local Knowledge, Climate Change causes of climate change, resilience, Climate Change Adaptation Planning (CCAP).*

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P3

Variability in rainfall characteristics in the semi-deciduous forest zone of Ghana

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Introduction

Increases in rainfall variability resulting from climate change can rapidly reduce land productivity, ecosystem resilience and heighten the risk of flood and soil erosion. Rainfall characteristics often represent the major driver of these processes (Morgan, 2005). The magnitude of erosion or flood is dependent on rainfall erosivity which may be related to the amount, intensity, kinetic energy, frequency and their distributions. The knowledge of the variability in the magnitude and distribution of these rainfall characteristics would no doubt facilitate the design of conservation systems for soil protection at vulnerable times and during critical periods. Such information is however very scarce in the tropics. Quansah *et al.* (1990) reported high annual total kinetic energy loads ranging from 41000 to 43000 J/m^2 with monthly peaks of 79000 and 9000 J/m^2 in August and September in the interior savanna zone of Ghana. The degree to which this and other rainfall characteristics varied within the year and over a long-term period were however not reported. The current climate variability has therefore necessitated adequate knowledge of these for the effective design of conservation systems to enhance ecosystem resilience as well as the development of adaptation strategies. It was in this context that the study was conducted to determine the variations, magnitude and distribution of rainfall amount, kinetic energy and erosivity over a long-term period.

Materials and methods

A 17-year rainfall records (1997 – 2013) from the Ghana Meteorological Agency, KNUST site, within the semi-deciduous forest zone of Ghana were collected and analyzed for rainfall characteristics such as the amount, kinetic energy and erosivity including their distribution. The Annual and seasonal kinetic energies of the rains were calculated as KE (J/m^2) =24.50P + 27.6 (Lal, 1984). The erosivity was calculated using the modified Fournier index (Arnoldus, 1980):

$$R = 5.44 \sum \frac{p2}{P} - 416$$

Table 1: Long-term mean and CV of annual and seasonal amount, K.E and erosivity of rains

Cropping season	Rainfall amount (mm)	CV (%)	Kinetic energy (KJ/m²)	CV (%)	Erosivity (MJ.mm/[ha.h.yr])	CV (%)
Annual	1376	17	34.11	18	554.24	44
Major	687	27	16.86	27	640.87	49.5
Minor	440	37	10.81	37	513.76	82

Table 2: Percentage reduction in rainfall in 5 and 10-year intervals

5-year interval	% Reduction	10-year interval	% Reduction
1997-2001	15.5	1997-2006	22.5
2001-2005	12.6	2000-2009	2.9
2005-2009	39.5*	2004-2013	10.5
2009-2013	5.9		
Mean	11.3	Mean	12.0

NB: * was an increase in rainfall amount

Where, R= erosivity; p = monthly rainfall amount (mm) P = annual rainfall amount (mm). The data were analyzed for variability in the magnitude and distribution of the parameters.

Results and discussion

The long-term mean monthly rainfall distribution showed rainfall amount to vary with the months with a peak in June and October in the major (March-July) and minor (September-November) wet seasons (**Fig. 1**) respectively. The results showed the major and minor wet seasons to contribute 50 % and 32 % respectively of the 17-year mean annual rainfall. Soil loss, runoff and potential incidence of flood would therefore be expected to be more in the former than the latter season. The result showed that the coefficients of variability of rainfall amount were 17 %, 27 % and 37 % in the annual, major and minor seasons (**Table 1**) respectively. Annual rainfall decreased by 11.3 % and 12.0 % in 5 and 10-year intervals (**Table 2**). This has potential negative impact on ecosystem resilience. Besides rainfall amount, several researchers have indicated that the kinetic energy (K.E) of rainfall is more closely related to its capacity to cause erosion. The kinetic energy ranged from 25.42 – 49.01 KJ/m^2, 8.86 – 22.69 KJ/m^2 and 5.08 – 20.34 KJ/m^2 for the annual, major and minor seasons respectively.

The contribution of the major and minor wet season kinetic energy to mean annual kinetic energy was 50 % and 32 % respectively as recorded for rainfall amount. Higher rainfall kinetic energy loads are partly responsible for the compaction of bare soils with a consequent reduction in soil infiltrability and generation of large volumes of runoff and potential flood. The onset of the rains and peak periods of rainfall kinetic energy require optimization of vegetative cover to cushion the soil against the erosive forces of rain drops and runoff. The annual erosivity (R) ranged from 146.9 to 1269.3 MJ.mm/(ha.h.yr) in 2006 and 2007 respectively with a mean of 554.24 MJ.mm/(ha.h.yr). The distribution of annual and seasonal K.E and R followed the same pattern (**Fig. 2&3**). The long-term major wet season erosivity varied between 100 and 1063 MJ.mm/(ha.h.yr) with a mean of 640.88 MJ.mm/(ha.h.yr). The CV of annual, major and minor season's erosivity were 44 %, 50 % and 82 % respectively. The high variability in these rainfall characteristics has significant implications for the magnitude of soil loss, runoff generation and potential flood incidence which could pose serious threats to the sustainable use of land resources.

Conclusion

Climate change is now evidenced in the high variability of rainfall characteristics in the semi-deciduous forest zone of Ghana as observed in this study. The high magnitude of the erosive forces (kinetic energy and erosivity) necessitate urgent and effective design and implementation of appropriate conservation measures, particularly during the early stages of crop cover establishment and the peak periods of rainfall to lessen the risk of erosion and potential incidence of flood and for proper soil protection.

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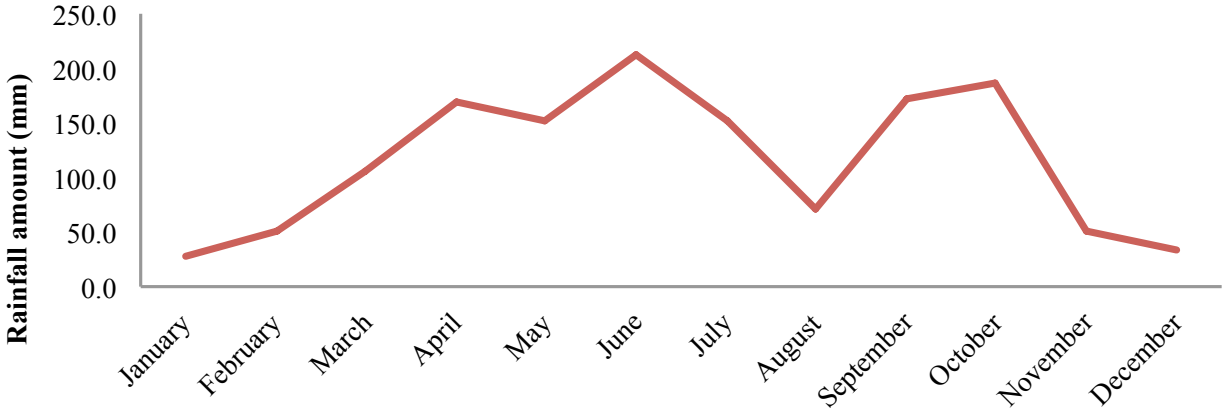

Figure 1. Distribution of mean monthly rainfall amount over a long-term

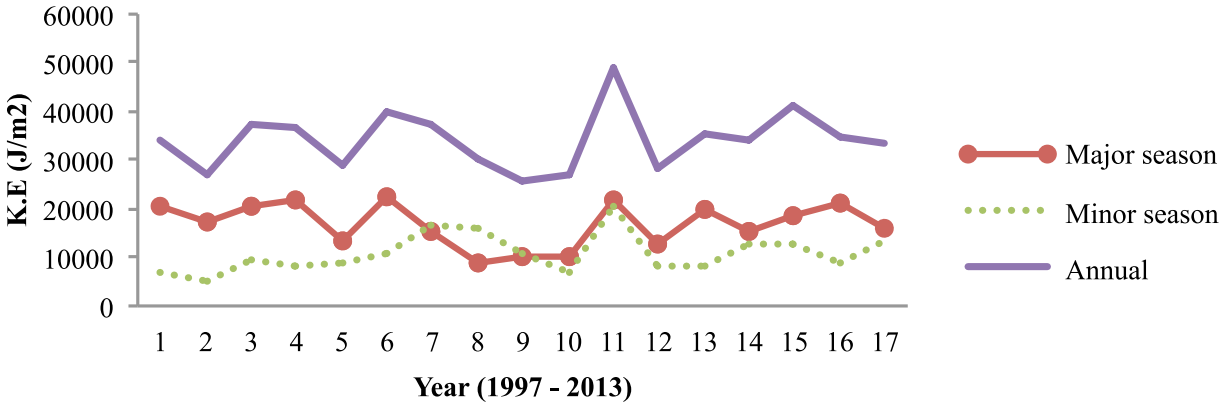

Figure 2. Distribution of Kinetic energy of rains

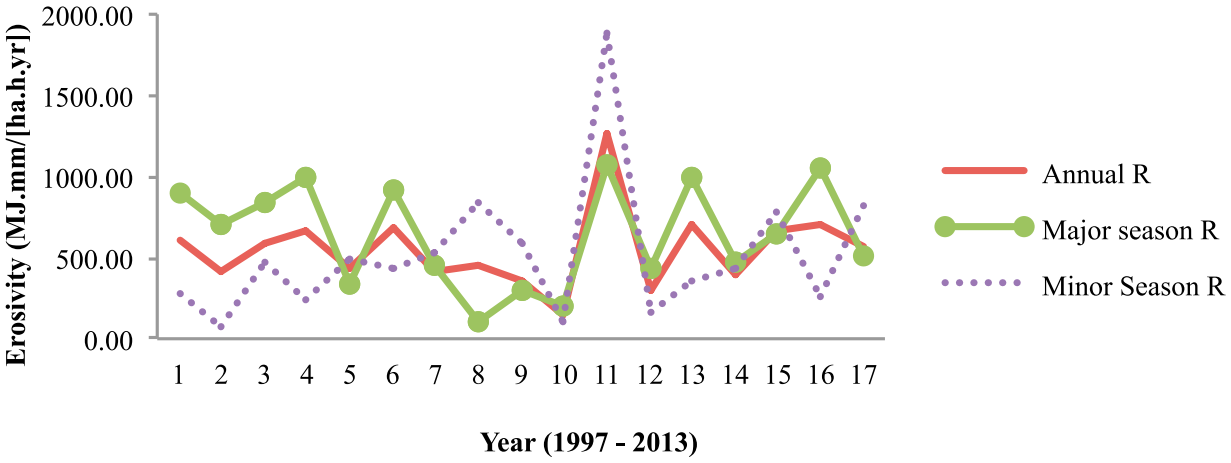

Figure 3. Distribution of annual and seasonal erosivity

P4

Comparative analysis on livelihood approaches, resilience and transformability in agro-ecosystems in West Africa

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Abstract

Seeking to explain resilience thinking theory into farming systems design practice, this paper seek to examine essential properties of complex systems dynamics and their relation with the systems that direct resilience and transformability in African smallholder agriculture. Agro-ecosystems dynamics surfaces from the aggregation of diverse strategies in reaction to changes in the agro-ecosystem context and are characterized by non-linearity, irreversibility, convergence/divergence and hysteresis. Further, it shall examine agricultural practices in connection to the diversity of rural livelihood approaches such as diversity as option system regimes, diversity as the outcome of transformability and diversity decided by changing agricultural contexts from existing literatures. The paper shall highlight a comparative analysis of West African agro-ecosystems that points to knowledge base for the ecological intensification of smallholder landscapes, policy and market developments. The methodology of the paper which is a secondary approach shall shed further notes that can be relevant to existing literatures that spans Agro-ecosystems in West Africa. In concluding remark, it shall draw some general conclusion.

Keywords: *Agro-ecosystems, livelihood, Resilience, Transformability, Agriculture*

P5

Communities vulnerability and resilience to climate shocks in the Niger basin of Benin

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Introduction

Agriculture in Benin is subjected to more risk and uncertainty due to climate variability and change through its high dependence on weather conditions. It is important to understand how climate change is affecting and will continue to affect the population, what will be the effect of climatic shocks in terms of vulnerability, and how to enhance the resilience of the population. Mastering these aspects will help to provide relevant policies to decision-makers in order to improve the well-being of these mostly poor populations. Thus, this research seeks innovative tools to assess vulnerability and resilience of communities to climate shocks.

Materials and methods

Area of the study and data

The study focuses on farmers of the Niger basin that covers 37.74% of Benin. The basin is located in the extreme north of the country and more specifically between latitudes 11° and 12°30' N and longitudes 2° and 3°20'40 E and has an area of 43,313 km^2. It covers five agro-ecological zones (AEZs) (wholly and partially) out of the eight of Benin.

The 1998 small farmer survey data from the International Food Policy Research Institute, the data from the survey which was implemented within the Niger basin of Benin in the 2012-2013 agricultural year on 545 farm households, climate data, and data from literature on the topic are used. Three-stage random sampling was used: first, municipalities within each AEZ, second, villages within selected municipalities and last, farm households within selected villages. AEZ V was disregarded, because only one of its municipalities is located within the basin.

Model

Vulnerability/resilience to climate shocks is assessed through an integrated approach, using vulnerability/resilience indicators,

Table 1. Regression results of vulnerability/resilience

Dependent variable: vulnerability / resilience Variables	Coefficients	P>|z|
Change in percentage in rainfall from long term mean	0.02	0.25
Square of change in percentage in rainfall from long term mean	-0.00**	0.03
Change in degree in temperature from long term mean	42.64***	0.00
Square of change in degree in temperature from long term mean	-65.24***	0.00
Proportion of households that belong to farmers' labor sharing groups	*0.75***	0.02
Proportion of households that belong to farmers' organizations	2.24***	0.00
Number of primary schools per household	52.71	0.16
Percentage of households that have access to electricity	-0.34	0.55
Constant	-2.50***	0.00
R-squared	**Overall=0.66**	**Within=0.70 Between=0.63**

***, ** Significant at 1%, and 5% respectively. *Source: Author's analysis with STATA 12*

which include a series of different socio-economic and bio-physical attributes corresponding to the Intergovernmental Panel on Climate Change (IPCC) definition of vulnerability, based on the methodologies of Deressa et al. (2008), Alinovi et al. (2009), and Damm (2010). Vulnerability and resilience are considered as opposite concepts, and vulnerability/resilience index is calculated as the net effect of adaptive capacity, sensitivity and exposure. Principal component analysis is used to assign weights to the indicators employed in the calculation of vulnerability/resilience indices for each village. The sensitivity and uncertainty test is carried out through the Monte Carlo (MC) analysis and changing the input data. As the multivariate approach produces normalized indicators with mean zero and it is difficult to compare the level of vulnerability/resilience over time, econometric analysis (unbalanced panel analysis) is carried out to allow forecasting of the indices. Variables that are used for the analysis capture the three aspects of the IPCC definition of vulnerability (exposure, sensitivity, and adaptive capacity).

Results and discussion

Strong winds were the major climate shock that farmers faced over the last 20 years or so far. It is followed by erratic rainfall, heavy rainfall, heat waves, floods, and finally droughts. The situation of the villages has been improved except for Kossou, Kpbébéra, Gantiéco, Kota Monongou and Moupémou. On average, communities of AEZ II are the most resilient to climate shocks, followed by AEZs I, III and IV in 2012. Sirikou is the most resilient community in 1998 and 2012, whereas the most vulnerable is Kota Monongou. The random effects are found more appropriate than fixed effects based on the tests. The results of the estimations are presented in **Table 1**. Many of the regressors have significant impacts on the resilience index. The impact of the two climate variables is non-linear. A given change in temperature from long term mean will strengthen resilience to climate shocks up to 0.33 degree Celsius, and beyond this threshold the impact will be negative, ceteris paribus. This could be explained by the fact that the crops will gain from carbon fertilization under a change less than 0.33 degree Celsius, ceteris paribus. The forecasts (up to 2100), done based on the econometric model, depict that climate shocks will have adverse impact on farm villages' resilience levels.

Discussion in terms of food and nutrition security

The situation of the farmers in terms of food and nutrition security will be affected if any action is taken. As climate shocks are predicted to impact adversely farming, food availability and access will be affected through a decrease of the part of the production devoted to self-consumption and cash income that should serve as means to get additional food. Moreover, farmers could not be able to meet dietary diversity. As these communities draw mainly their livelihood from agriculture, this could lead to vulnerability to food insecurity.

Conclusion

The analyses reveal that farmers are vulnerable to future climate shocks. Public policies should encourage formal and informal social networks that enable group discussions and better information flows and improve adaptation to climate shocks. They should strengthen the existing adaptation strategies practiced by farmers. Moreover, results indicating significant differences among villages and AEZs suggest that adaptation technologies should be targeted to the various villages and AEZs to enhance their specific adaptation potential.

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P6

Residents' perception and adaptation/coping strategies to climate-related disasters in Bankpama, Wa West District, Ghana

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Introduction

Climate change has the propensity of bringing considerable change in the hazard profile and its interaction with the dynamic vulnerability and risk profiles of countries (Prabhakar 2009). The Ministry of Environment, Science and Technology [MEST] (2010) of Ghana observed that climate change is a threat to Ghana's development prospects, especially in deprived communities. MEST (2010) also maintains that "the way in which people experience climate shocks varies across different social groups, geographic locations and seasons of the year, with men, women and children all experiencing different levels of hardships and opportunity in the face of climate change". Consequently, human perceptions have been identified as pivotal elements of assessing intricate environments and systems as well as relevant attitudes and behavior in diverse disciplines.

While vast empirical evidence exists to explain the concept of climate change and its effects globally, there is paucity of knowledge on how residents of flood and drought prone (hotspots) communities in Ghana perceive and deal with climate associated stresses as drought, flood, storms and extreme temperatures. Consequently, this study explores how residents of a climate-induced disaster prone community (Bankpama) perceive climate stresses. Further, the study examines their lived experiences as well as coping strategies against disasters in the community.

Principally, the motivations for the study are two folds: first, it is expected that the study will contribute to the body of literature on climate-related disasters and coping/adaption mechanisms, by providing a more in-depth understanding of the phenomenon from the perspective of respondents. Current studies on the subject have dealt with these issues quantitatively hence have not effectively articulated the lived experiences of the affected persons. Second, it is anticipated that the study will provide some policy directions on how to support such affected communities to sustainably adapt and/or cope with climate change impacts.

Materials and Methods

This study was conducted in Bankpama in the Wa West District (WWD) of the Upper West Region, Ghana. Geographically, the WWD is bordered to the north by the Nadowli District, east by Wa Municipality, south by Sawla-Tuna-Kalba District and west by Burkina Faso. Bankpama lies close to the banks of the Black Volta River, which takes its source from Boulé, South Western Burkina Faso (Wa West District Assembly [WWDA] 2007). Bankpama was selected for this study because it happens to be one of the communities, including Baleufili, Chietanga and Zowayeli that went through some comprehensive agro-ecological, engineering, and socio-economic resilience/vulnerability under the CECAR-Africa Project (2012) on "Enhancing Resilience to Climate and Ecosystem Changes in Semi-Arid Africa: An Integrated Approach". It is worth noting that studies have also advanced evidence of climate instability and change occurring in the Northern Region of Ghana, and Bankpama is no exception. For instance, Yengo et al. (2010) hinted on the incidence of climate-related disasters, such as floods, storms, bushfires and rising temperatures in the north. A reconnaissance survey on the study area also suggests that the study community is not insulated from the aforementioned climatic stresses. However, by emphasizing on Bankpama, this study hopes to identify and bring out for discussion some salient area-specific issues in dealing with climate-related disasters.

The study (guided by the phenomenological approach to qualitative studies) purposively selected 10 community elders, 10 men (young men inclusive), and 10 women (young ladies inclusive) from the community, and using Focus Group Discussions, solicited people's perceptions on climate-related disasters, experiences and adaptation/coping strategies. The data was transcribed and presented in a form of narratives, based on lived experiences and observations.

Results and Discussion

Perceptions on climate-related disasters

The study established that flood was one of the climate-induced disasters plaguing Bankpama. Interaction with the elders revealed that the frequency and severity of this disaster were rising. They agreed that it used to occur every three years starting from 1983, but now comes every year since 1990, whether or not there are torrential rains. They lamented the destruction of their crops and property during such occurrences. As to the cause of floods, the elders were generally uncertain. A 78 year old man had this to say: *"as for me, I don't know what this mystery is all about……. We need rains to water our crops so that we can get food to eat, but we don't, yet a lot of water comes all of a sudden and wash away our food crops and destroy our properties, why? Only God can help us……"* The women and young women in the community also conceded that floods were occurring every three (3) years in the past, but have now become an annual phenomenon. They were, however, oblivious of the cause (s), except for a 23 year old girl who made an observation: *"hmm,*

I think that the world is simply coming to an end…. that is why all these bizarre things are happening to us in our community……God knows best" On the same subject, the men and young men held the view that the occurrence of floods was escalating, leading to destruction of crops and buildings. It was, nonetheless, interesting to note that most men and young men had a clue about the cause of the phenomenon. A 43 year old man exclaimed: "*as for floods in this community, we all know the cause; it is basically the opening of the Bagri dam upstream each year that results in the flooding of the Black Volta River, which destroys our property.*" From the foregoing, it is palpable that the occurrence of floods was increasing, but the exact cause seems unknown to most residents, owing to the mixed responses adduced. While others thought it was simply an act of God, some ascribed it to the opening of the Bagri dam upstream.

When it came to drought, the majority of respondents noted that the frequency and severity of drought were rising yearly, destroying crops and increasing weather temperature. One of them made a claim that: "*the drought is indeed here, the weather is so hot; we use to have early rains by March through to November each year, but now, we experience early rains somewhere late April and continually have it erratically up to October. It is so severe this time that our animals and crops are dying by the day."* [71 year old elder]. A 58 year old woman similarly observed: "*hmm, were are suffering from this curse a lot…… we can't even get enough food and shea fruits to pick for a living because we don't have enough rains*."

The residents of the community largely could not easily comprehend why storms strike them yearly amid extended drought periods. Elders, men and women alike were in the affirmative that storms were becoming severe and lots of properties were being loss to them yearly. They speculated the phenomenon could be ascribed to loss of vegetation cover and felling of trees which serve as windbreaks. To this, an 18 year old young man lamented saying that: *"our community is really feeling the pinch of the strong winds lately. My dad has to repair the roof of our house each year because of this…….our crops in the farms are also destroyed at times."* Another respondent stated that *"I think the gods must be angry at us, that is why we keep on getting this punishment. We are engaging in unacceptable acts, such as having sexual intercourse in the bushes, which incur the wrath of the gods on us."* [A 66 year old woman]

Coping and adaptation mechanisms

Consequently, it was gathered from study that though residents appear very vulnerable to the abovementioned disasters, they have some strategies that help them to cope and/or adapt to the stresses. As regards floods, residents, especially farmers noted that they adapt by farming on hilly or high lands to prevent crop inundation. A 35 year old farmer said: *"I know flood will always occur each year, so I simply wouldn't farm on low lands"*. Another avers saying: *"…….if I farm on a hilly area, at least, I can still harvest something small in the event of any flood…..this is the only way out for me."* [38 year old women]

In relation to drought and high temperatures, it was observed that respondents could do very little about such occurrences in the community. However, an elder responded by saying that *"though it is not so effective a strategy, I adapt by cultivating crops with shorter maturation period (2 months) to hedge the drought"* [70 year old elder]. A respondent also mentioned that *"my household simply copes by sleeping outside when there is so much heat, especially in March, to prevent the deadly Cerebral Spinal Meningitis disease which is occasioned by excessive heat."* [21 year young girl]

As to storms, the study showed that almost all the respondents had the same strategies against storms which include the planting of trees around houses to serve as windbreaks and placing of heavy boulders and logs on roofs to prevent them from being ripped off. A fifty (50) year old man confirmed by saying that: *"the only way out is to place these very heavy stones on my roof, which is very effective……. I also try to plant some trees to serve as windbreaks, but they eventually die off because of the drought and its attendant heat."*

Conclusions

The study concludes that residents of the community perceived flood, drought/extreme temperatures and storms to be increasing in severity and frequency. It was also found that while some residents ascribed the cause of disasters (such as floods, drought and high temperatures) to spiritual punishments from God and gods, others were ambivalent. However, they recognized felling of trees and burning of bushes as being causes of storms. From the foregoing, it would be prudent for various agencies, such as the National Disaster Management Organization (NADMO), NGOs and others concerned entities to enlighten the community on what the main causes of floods and droughts are. It is also important for them to be empowered and educated on long term remedial measures against these disasters.

It was interesting to note that residents had coping strategies against the aforementioned climate-related disasters, however, some of these strategies may not work if disasters continue to increase in frequency and severity. To this end, the government and other quasi-governmental organizations could assist in increasing residents' access to grants and credit which may lessen their susceptibility to natural disasters and eventually, help them to recuperate, adapt effectively to the impacts of disasters. Second, effective measures could also be taken by the government to relocate the community to a safer place since the occurrence and severity of natural disasters are highly unpredictable.

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P7

Collective action and farmers' private adaptation to climate change: evidence from the savanna region in Togo

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Abstract

Climate change is a reality and farmers in developing countries often face capital constraints in adapting to climate change. Can collective action at household level be utilized to facilitate the adaptation? This study uses principal component analysis to recover the underlying latent variables of collective action at household level, given the fact that collective action is not directly observed. Two factors, namely cooperative capacity and effective cooperation, are hypothesized to capture collective action and were further used in a two-step multivariate probit to examine whether collective action is systematically linked to adaptation to climate change. The results suggest, in general, that collective action at the individual level in the form of cooperative capacity and effective cooperation does affect farmers' most private adaptation to climate change. Consequently, an important policy message from these results is that enhanced farm households' participation in collective action initiatives can significantly increase the adoption of important adaptation strategies, such as water and soil conservation and irrigation practices by farm households. Another important result of this study is that climate change could enhance collective action initiatives. Given that farmer groups are not always successful, there is a need to better understand under what conditions collective action is useful and viable. This should be the target of future researches in collective action area.

Keywords: *climate change, adaptation, collective action, agriculture, the Savane region of Togo, two step multivariate probit.*

P8

Evaluating the impact of cereal banking on food security and resilience building of rural households in the Gambia

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Abstract

Using Propensity score matching built on a stratification and randomisation, this paper attempts to evaluate the impact of cereal banking on Food and Nutrition Insecurity. Cereal Banking is a community-based risk management strategy which involves buying of food during harvest when prices are low and storing for consumption during the lean period when food prices are high. The purpose is to smooth consumption in rural communities and households through the year.

The results of our matching indicate that communities that are relative poorer, living further away from markets and are vulnerable to high inter-seasonal food price changes have a higher probability of adopting and sustaining cereal banking schemes.

Our impact evaluation show that cereal banking has far reaching positive impacts on food availability, accessibility and nutrition at individual, households and community level. In particular, the results show an average treatment effect of 25 – 30% reduction in both the food gap and inter-seasonal food price variability in treated villages. Cereal banking enhances food self-sufficiency by an average of 11.6%. The Difference in mean between children from households in treated villages and control villages show significant differences of more than 16 percentage points between the average rates of malnutrition of children in treated households and children from control villages. Like other studies, we observe that the literacy of household head significantly improves the nutritional status of children. Similarly, provision of farming implements has a significant impact on food and nutrition security of rural households.

However, the impact on wealth seems to indicate that for cereal banking to enhance wealth and other livelihood outcomes, it must be consistently operated for a while.

P9

Soil properties of six communities in the northern region of Ghana as affected by crop species and location

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Abstract

Random soil samples were collected from maize, rice, groundnut and yam fields in six drought prone communities{(Fihini (F), Dabogushei (D), Kpalgun (K), Zergua (Z), Yoggu (Y) and Cheshagu (C)} of the Tolon district in northern Ghana with the view of understanding the effects of crop species and field location on some selected soil properties. The four target crops (maize, yam, groundnut and rice) were selected based on a household survey which identified them as the major crops grown by farmers in these communities. About 426 samples taken from 426 farms, to a depth of 25 cm were air dried, then sieved, and analyzed. Chemical parameters measured were pH, electrical conductivity (EC), total nitrogen and organic carbon (OC). Particle size distribution and texture were the only physical parameters determined. Even though the soils of the Tolon district are reported to have been formed from the same parent material (Voltaian sandstone), statistically significant differences were observed among crop species and communities for all parameters. The pH was lowest in Y averaging 5.77 and highest in F (6.22). The OC and total N were lowest in F, averaging only 0.59 and 0.83 respectively. The crop-wise analysis showed that rice field was the highest in OC and clay content and the lowest in pH. Principal component analysis (PCA) was carried out crop-wise using data of four soil parameters (pH, EC, OC and silt content). The proportion of variance to PC1 ranged from 0.29 to 0.40, which was not as high as expected. The Eigen value for PC1 ranged from 1.15 to 1.60. Among the four soil variables, pH and OC showed constantly higher positive correlation to PC1 in maize, yam and rice fields, but negative correlation in groundnut field. The Six communities are rather separately plotted in the PC1-PC2 correlation graph where the similar pattern was obtained for maize, yam and rice. It was shown that soil properties measured are affected by crop species and field locations and the soils have developed distinctive physico-chemical properties as result of continuous cropping operations in the communities.

P10

Application of DPSIR framework to extreme climatic effects in Northern Ghana

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Abstract

Northern territories of Ghana are well noted for experiencing extreme events such floods and droughts and other associated environmental challenges. The extreme events have been attributed to the global climate change phenomenon which manifests itself through changes in distribution, intensity and temporal occurrence of precipitation. The changes have had diverse implications for agriculture and other land based (processes) that are dependent on natural climate as a moisture source for cultivation, food security and general livelihoods of the people which is mainly agrarian. The negative effects of such events include loss human and properties worth a significant proportion of regional GDP. Vulnerability to climate change effects is often defined as a function of exposure, sensitivity and adaptive capacity for which many assessment indices employ physical, natural, human, financial and social capitals as indicators of estimation. However these factors to a large extent fail to consider the complex cause – effect nexus between human societies and the environment. The objective of this study is to analyze anthropogenically triggered environmental change and its contribution to human vulnerability extreme events in the Wa-west district. The study will employ DPSIR framework as tool to draw out the linkages.

Keywords: *DPSIR framework, Flood, Droughts, Livelihoods, Food security*

P11

Estimation of USLE's C-Factor using vegetation indices (VIs) for soil erosion modeling in Lake Bosumtwi

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Abstract

Water erosion is one of the worrying environmental challenges in high altitude landscapes that can result from climate change. Bosumtwi basin is exposed to erosion particularly due to the sloppy and rough nature of the terrain as well as the increasing amount of human activities on the landscape. Universal Soil Loss Equation (USLE) is a commonly used model in estimating soil loss by water. The USLE's cover and management factor (also known as *C*-factor) represents the combined effects of plant, soil cover and management on erosion. Remote sensing vegetation indices in the estimation of C-factor has proven to be reliable, and useful when considering inaccessible and large regions. *C*-factor is mostly generated from Normalized difference vegetation index (NDVI) despite the availability of other indices believed to overcome the inherent problems associated with NDVI. This study compares NDVI with EVI, in their capability to map land cover types, to be applied in *C*-factor estimation. A plotted graph of two divergence statistics against class numbers help determined the optimal number that the Hypertemporal image can be classified into. The resulting thematic maps were reclassified based on their profile similarities and were compared with already classified and validated ASTER map. The overall accuracies of the two VI maps were both high (80% for EVI and 70% for NDVI) and the kappa statistics of 0.7 and 0.5 for NDVI and EVI respectively. A composited image of 2010 Hypertemporal MODIS EVI was applied in developing a *C*-factor model by the Exponential Function (E. F) approach. The output was validated by comparing the developed *C*-factor model to literature *C*–factor values of the sub-region. The *C*-factor model showed an overall accuracy of 76% and 0.6 kappa value.

Keywords: *Cover and management (C) factor, Erosion, Modeling, Vegetation Indices (VIs)*

P12

Assessment of spatio-temporal patterns of terrestrial ecosystem to climate variations using satellite data in Ghana

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1. Introduction

Agriculture in both industrialized and developing countries is a unique sector, characterized by complex issues and problems, ranging from macro (economic) policy levels all the way to the micro (smallholder) farming household and field plot levels. Agriculture, being predominantly a (small-scale) family and/or communal enterprise differs in fundamental ways from administrative services and industrial sectors in terms of relative unpredictability, uncertainty and variability in bio-physical (soil and weather) conditions on which the primary production processes rely. Also, there is a huge diversity in production strategies and objectives among farming households as well as household individuals. Agriculture in Africa is mainly seasonal and faces high levels of risks, which are in-turn compounded by poor infrastructure and isolated rural communities (Stoop and Hart 2005). Fluctuating market and trade conditions, as well as political instability further add to farmer uncertainty. Agriculture therefore, faces rather unique problems with respect to research and development including the planning, implementation and evaluation processes that are involved as well as the assessments of impacts at various levels (Eicher, 1999).

In African countries, sustainable agriculture is the key to the food security. However, in the present scenario of climate change that results in various climate related disasters, such as flooding and drought, causes instability in the agriculture production. Therefore, new agricultural techniques are to be developed to supply a constant yield in the climate change scenario. In this study the focus is on terrestrial ecosystem and its multi-temporal changes to monitor its responses with

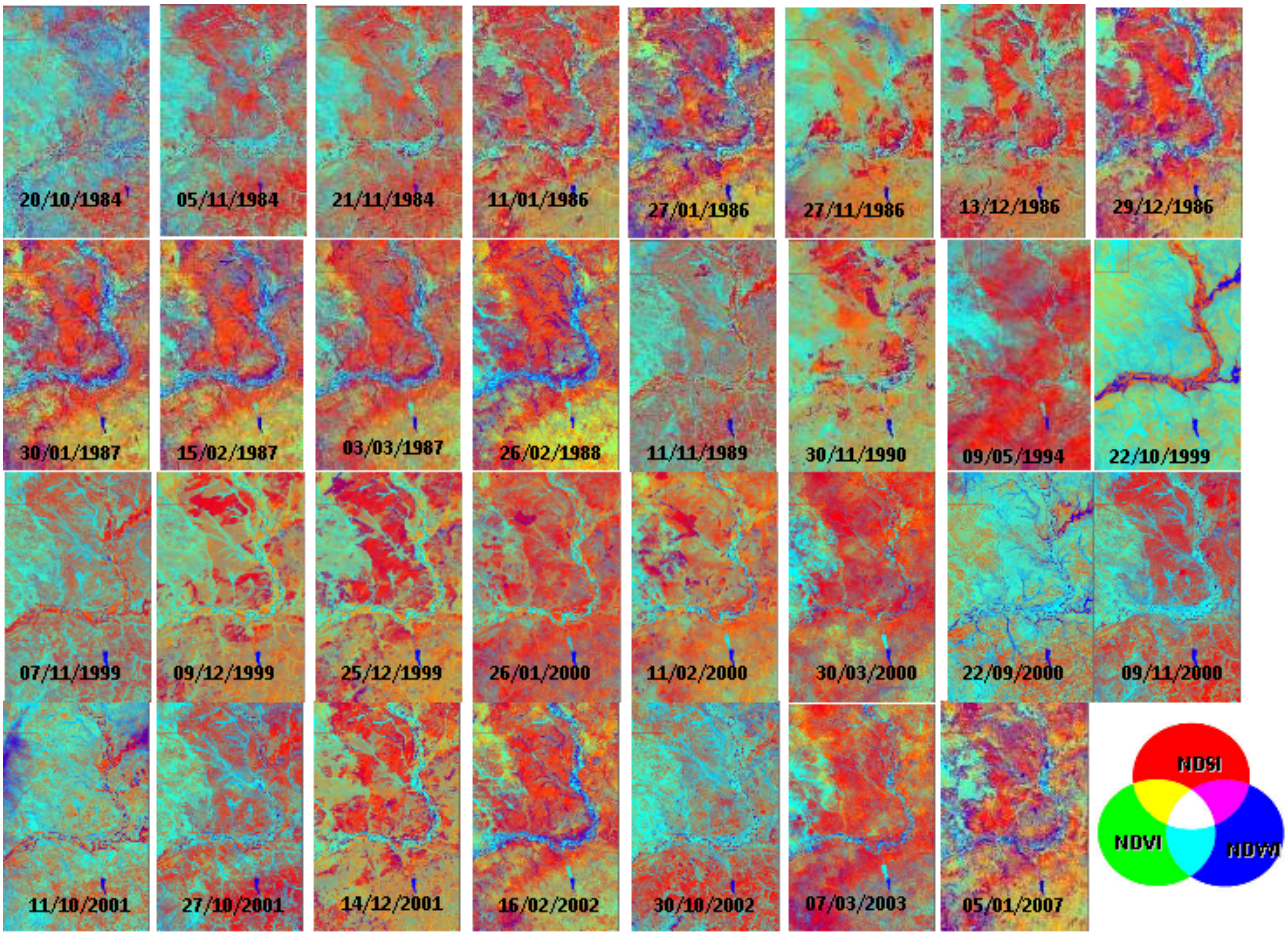

Figure 1. Landsat based multi-temporal changes in the vegetation indices of Tolon district

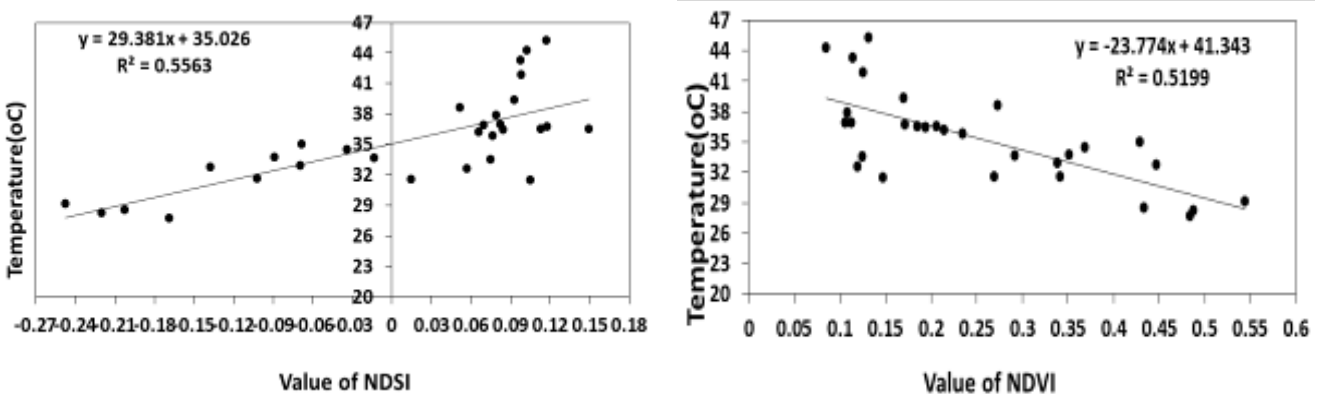

Figure 2. Changes in the vegetation indices with respect to ground temperature in Tolon district

the climate variations. The terrestrial ecosystem that includes forest and agriculture attracts various researchers to simulate the responses of the vegetation in different scenario of climate variable. Based on the results agriculture practices can be modified to minimize climate change impacts on production.

2. Study area

The study was conducted on Ghana. Vegetation and its seasonal responses were monitored in whole Ghana (further divided into northern Ghana and Southern Ghana). The study mainly focused on two sites: Tolon and Wa West districts. Tolon is considered as drought prone area, whereas Wa West is considered as flood prone area because of overflow from river Black Volta. Rainfall and temperature patterns in the study area are highly variable. Average annual rainfall ranges between 900 – 1000mm. The rainfall is normally irregular, intermittent and torrential. The rainy season starts from April and reaches maximum in August/September. This is the period of intense

farming activity. Temperature in the study area ranges between averages of 25°C (minimum) to 36°C (maximum). The highest temperatures are normally recorded in March and can rise as high as 45°C. The lowest temperatures are recorded in January.

3. Methodology

3.1 Satellite data

In this study Landsat and SPOT vegetation data were used. All clouds free Landsat data from 1984 - 2013 and SPOT vegetation data from 1999 – 2012 were collected to monitor seasonal changes in the vegetation. Various vegetation indices (NDVI, NDSI, NDWI, SAVI etc.) have been used to monitor vegetation conditions and their phonological changes. Based on this information, relationship of the vegetation indices with the change in temperature and precipitation was investigated. The most common and widely used vegetation index is the NDVI developed by Rouse et al., 1974. Despite its intensive use, the relationship between the NDVI and the vegetation is known to be strongly affected by soil reflectance (Huang et al., 2013). Therefore, other vegetation index such as SAVI was also used (Avtar et al., 2013).

3.2 Ground data

We have collected daily average rainfall and temperature data of Ghana from Ghana Meteorological Agency. This data has been used to monitor the changes in the vegetation indices with respect to the changes in climate variables.

4. Results and discussion

Processing of satellite data has been done for the particular study area to monitor the multi-temporal changes in various vegetation indices. **Figure 1** shows the multi-temporal changes in the Landsat based vegetation indices in Tolon district and the dry and rainy season can be clearly distinguished based on the spectral reflectance of the vegetation. **Figure 2** shows the changes in the vegetation indices with respect to the ground temperature in Tolon district. It shows a significant relationship between ground temperature and changes in the value of NDSI and NDVI. The value of the NDSI increases with the increase in the temperature because of more exposed soil. However the value of NDVI decreases with the increase in the temperature mainly because of decrease in the greenness of the vegetation. Similarly we have done further analysis and trying to simulate these results with climate change projection models.

5. Conclusion

The results show that the vegetation indices can be used as an indicator to monitor physiological changes in the terrestrial ecosystem and they have significant relationship. Phonological study of terrestrial ecosystem is important to monitor the impacts of climate change. If vegetation parameters with respect to the climate change projections can be simulated then a new agricultural technique can be developed to supply a constant yield in the climate change scenario. Therefore, the study about impacts of climate change on terrestrial ecosystem will be useful for the public and policy makers.

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