Welcome to Africa

Proceedings of the Summer-School Workshop

2015

Scientific Cooperation Network
on Climate Change Adaptation
in Eastern Africa

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“Welcome to Africa”

Scientific Cooperation Network
on Climate Change Adaptation

Proceedings from the Workshop

26 – 29 May 2015

Technische Universität Dresden
Tharandt, Germany

In the Mountains of Zittau, visit of the Zittau Municipal Forest Enterprise

The “2015 proceedings” document the contributions of the third and final annual Summer-School Workshop of the “Scientific Cooperation Network on Climate Change Adaptation”, a project within the DAAD program “Welcome to Africa”. The workshop took place on 26-29 May, 2015 at Tharandt campus of the Technische Universität Dresden and at selected locations in the region.

The Summer School enabled not only South-North cooperation, but also South-South cooperation. For this purpose, the project invited African graduated students, together with senior researchers from the partner institutions, to learn from the participating colleagues, local experts and practitioners, on ways to cope with climate change.

The contributions of the proceedings mirror the diversity of the participants, in regard of their regional and professional backgrounds, their research interests as well as in regard of their experience in writing scientific texts. While some are well-experienced seniors, for others it was the first time to draft a paper. In this sense, we ask the readers for understanding for formal weaknesses, and welcome the newcomers and appreciate the diversity, which enriches and enables innovations.

It is a great pleasure to thank all presenters and authors for participation and fruitful contributions. We express our thanks to the Technische Universität Dresden for hosting, to the ‘Gesellschaft von Freunden und Förderern der Technischen Universität Dresden e.V.’ for the sponsoring of the excursion to Oberlausitz, and to all excursion partners for the warm welcome and for sharing their expertise with us. Special thanks to the Deutscher Akademischer Austauschdienst (DAAD) and to the funding institution, the Ministry of Education and Research (BMBF), for both enabling the mobility and to build the network!

On behalf of the project team,

Eckhard Auch

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Abstract

Research is placed in a socio-ecological coevolution context and embedded in a constructivist approach. It has a strong development oriented focus and is fueled by both, traditional and modern knowledge. The constructivist approach implies that all research steps are discussed with involved stakeholders from theory as well as from practice (Pretzsch et al 2014). Following the theoretical construct of Habermas (1965) who differentiates the three research spheres analytical, humanistic and critical sciences, all three spheres are covered. Beside the traditional analytical sciences based research process, which is characterized by the formulation hypothesis and its verification or falsification, hermeneutic research is of special importance to understand climate change processes. Further on the application of critical sciences is important for action, emancipation and change.

Climate change adaptation is a very complex process. In recent years, a methodological framework was elaborated with a focus on the implementation of socio-economic field laboratories. They have character of a long-term research & development (R&D) process on the level on local communities or households, involving local people as well as scientists and students. The process covers all stages of an innovation cycle; a common diagnosis as baseline, looking together for innovative solution, often based on scenario techniques, creative workshop and information exchange and finally common implementation. The process

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follows and adaptive management strategy; there are strong feedback mechanisms and frequently there are setbacks in the diagnosis stage.

Because of the long duration of the R&D process and the successful implementation of field, which may take more than ten years, there are strong limitations in their implementation combined with a high moral responsibility of scientists. In the situation of the Cooperation with East African Universities, this might be buffered by a strong cooperation network, which survives normal funding cycles.

Keywords: constructivism, socio economic field laboratories, climate change adaptation, action research

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Climate Change Adaptation in Saxony

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Abstract

Two larger projects on climate change adaptation, REGKLAM and INTERCLIM, were conducted in Saxony, to elaborate recommendations for Saxony, an industrialized country with larger technological facilities and strong efficiency demands on its economic activities. Methods employed and selected results on mean annual temperature and precipitation as well as recommendations for the sectors of water, forestry, agriculture, public health and urban planning are summarized and discussed.

Keywords: climate change adaptation, REGKLAM, INTERCLIM

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1. Introduction: challenges in rural development

Climate change affects globally all regions, without regard of nations, although not in the same way and magnitude. Therefore, people everywhere, in the Tropics and in the Temperate, in the Global North and in the Global South have to design responses on their climate change challenges. For the research and for the academic discourse on climate change adaptation/mitigation (CCA) in tropical and subtropical regions, like it takes place in the Welcome to Africa Network, a look on an industrial country with larger technological facilities and strong efficiency demands on economic activities might be inspirational and might give ideas for CCA research in the tropics. The contribution analysis two larger projects on CCA in Saxony, the REGKLAM and the INTERCLIM projects, by drawing on the project's publications. The method employed and the archived results are critically discussed in regard to CCA research in the tropics.

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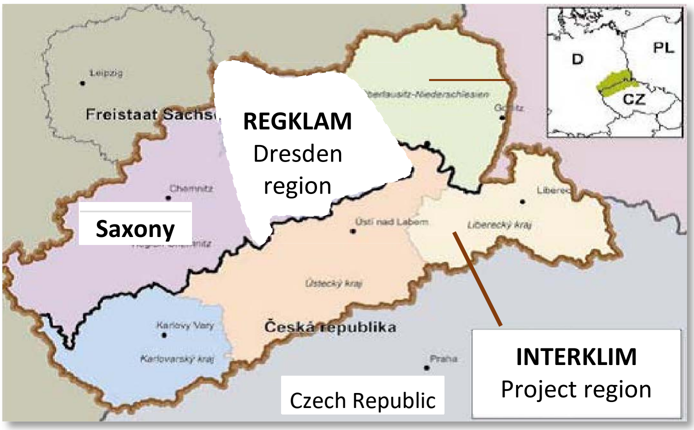
The aims of the contribution are to (1) present CCA challenges in Saxony, (2) to present the approaches of research to contribute to the CCA strategy, (3) to identify lessons learned for research on CCA in both global North and global South.

2. CCA research in Saxony: cases and methods

2.1 The projects

INTERKLIM[*]

is a climate-cooperation for the Czech-Saxon border region (see Fig. 1) and run 01/2013 - 12/2014. The project was implemented mainly by governance agencies and research organizations from both countries. The objectives compromise a joint climate change prognosis and the elaboration of recommendations for climate change adaptation for agriculture, forestry, water management, health, economy, tourism.



D = Germany, PL = Poland, CZ = Czech Republic. Source: SLfULG 2014: 2, modified

Figure 1: INTERKLIM and REGKLAM projects regions

REGKALM

is an “actor network for climate change adaptation in Dresden region” (see Fig. 1) and run 2008 - 2013. Academic units of the Technische

[*] www.interklim.eu/

Universität Dresden and Bergakademie Freiberg as well as the municipality of Dresden implemented the project. The objectives compromise the generation of climate change models and scenarios, the elaboration of regional strategies and specific recommendations for water management, urban planning, and land use.

2.1 Methods employed

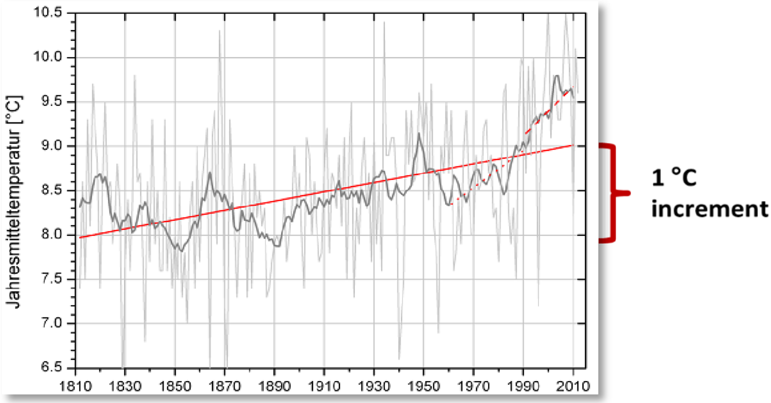
Both projects follow a two-phase approach with (1) model and scenario development and (2) generation of sectoral strategies and recommendations. The REGKALM project organized the second phase in a strategy development and in sectoral recommendations. Nevertheless, the published results for this phase are dominated by detailed sectoral recommendations. Steering committees were formed to guide the processes (see Fig. 2).

Figure 2: REGKLAM Project structure

2.2. Diagnosis and scenarios

The analysis of historical climate data shows a 1 °C increment of the meant annual temperature within the last century for Dresden (Fig. 3). Despite the high fluctuation between the years, the temperature increment over the century is obvious.

The precipitation in the study areas is modified by the relief, from 650 mm in the northern plains up to 1030 mm in the highest parts of the Ore Mountains in the Czech-Saxony border region, with 810 mm as average.

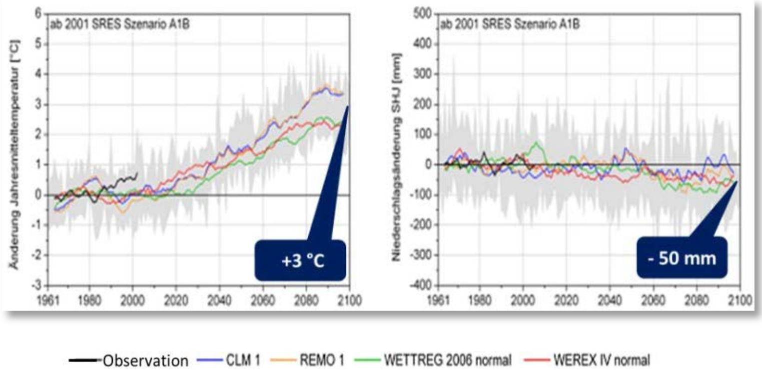


Floating 11-year mean. Source: REGKLAM (2013: 6)

Figure 3: Evolvement of mean annual temperature in Dresden from 1810 to 2010

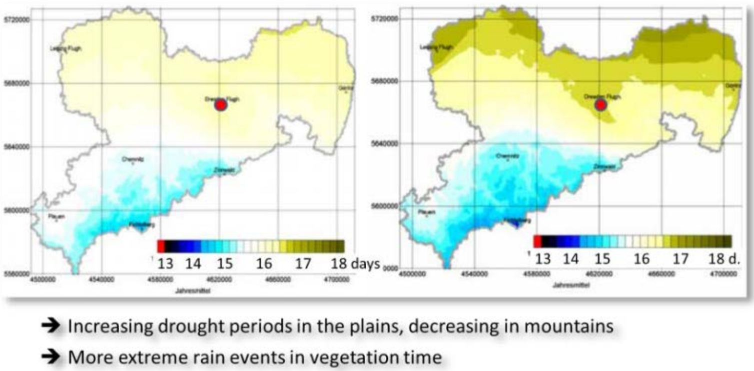
The projects employed various climate prognosis models and used local/regional datasets for calculating scenarios. The obtained climate scenarios are dominated by two trends: (1) further increment of the mean temperature for approx. 3 °C within the next century, and (2) a decreasing precipitation of approx. 50 mm until 2100. Figure 4 shows the courses of the different scenarios, determined by the models employed. The black graph (until 2004) marks the measured values and can be used to evaluate the validity of the models.

The relief of the landscape will override these two main trends. The plains (northern part of Saxony) will receive higher temperature and less precipitation, which will mostly be perceived as negative. The mountainous areas (southern part of Saxony and border region with Czech Republic) will benefit from a milder climate and shorter drought periods (Fig. 5).



Left: changes annual mean temperature, right: changes annual precipitation. The black graph demarcates observations, the colored graphs prognosis of the employed models. Source: REGKLAM (2013a:8)

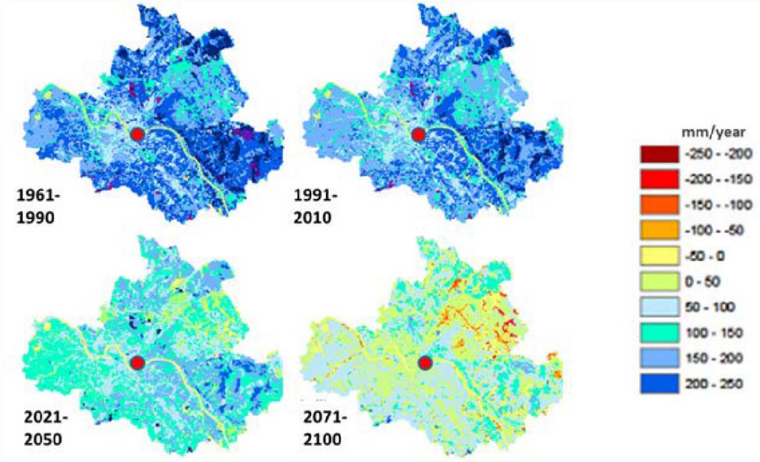
Figure 4: Climate scenarios for Dresden region: modeled changes



Prognosis of drought periods defined as less/equal 11 days precipitation below 1 mm. Source: REGKLAM P3.3.1e (2013c: 7).

Figure 5: Mean duration of drought periods

The second trend (decreasing precipitation of approx. 50 mm until 2100) will affect the groundwater regime significantly. As the scenario in Fig. 6 displays, the groundwater recharge is supposed to be dramatically reduced until 2100. Causes are the diminished precipitation as well as the changed precipitation pattern with higher and more extreme rainfalls in the vegetation period and lesser precipitation during winter. Precipitation in winter is substantially stored as snow and considered as easier to infiltrate, while heavy rains in summer (vegetation period) largely leave the hydrological system as run-off. Cultivation of rivers and watersheds fuel the surface runs off and risks of inundations.



Source: REGKLAM 3.2.2e (2013b: 6)

Figure 6: Groundwater recharge scenarios for Dresden region

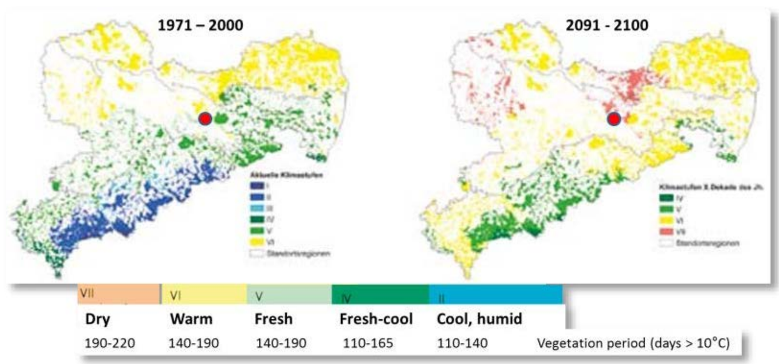
3. Selected sectoral recommendations for CCA

3.1 Water management

Groundwater levels are sinking and highly alternating since the 1980s, with climate as most important driver for these dynamics. The problematic trend will be enforced by the predicted decline of precipitation in spring and summer, in coincidence with the predicted higher temperatures will lead to reduced groundwater formation. The increased utilization of groundwater for production of drinking water (boreholes) are seen as contributing significant to the disturbance of the regime. While the project could not elaborate a qualified recommendation for action (SLfULG 2014: 95 ff.), the water administration (State Dam Authority) already considered the findings for an adaptation of their strategy: initially it was planned to reduce the water protection areas in catchments feeding the drinking water reservoirs, as a consequence of the predicted decrease in inhabitants in the region. Now, as a measure for climate change adaptation, the planned reduction will not be implemented, the oversized capacity will be continued, under acceptance of the higher costs, but for the benefit of a higher droughts resilience (personal communication with Mr. Sudbrack, Saxony Dam Authority).

3.2 Forestry

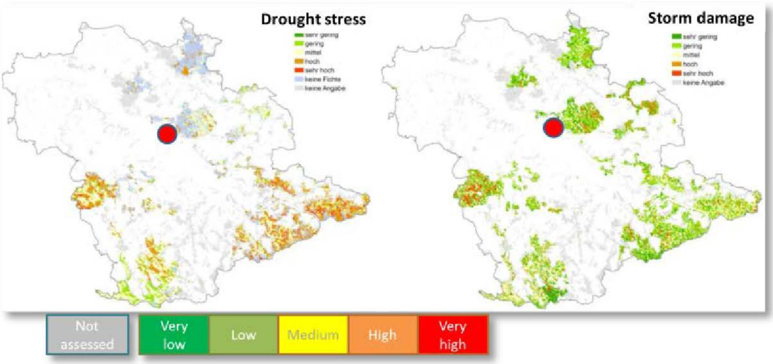
The scenarios describe a spatial shift of growth conditions from the low land's plains to the mountains and from north to south. For forest planning and management "climate levels" were defined by days with mean temperature > 10 °C (Fig. 7). These units are used to evaluate and recommend species for forest regeneration and production goals. Since the production (rotation) periods in Saxony for most timber species are beyond 100 years the relevance of these information for decisions on future tree species composition and stand structure cannot be highlight enough.



Source: SLfULG 2014: 77

Figure 7: Determination of current and future climate levels for forestry planning

The prolonged drought periods will not only limit volume production, it will also lead to increased drought stress with higher risks of fire and insect calamities. In addition, storm events are predicted to increase. To quantify these challenges specific scenarios for risks of drought stress and storm damage were calculated (Fig. 8). A special analysis was done to identify the stands with high priority for restocking of forest with resilient species (Waldumbau).

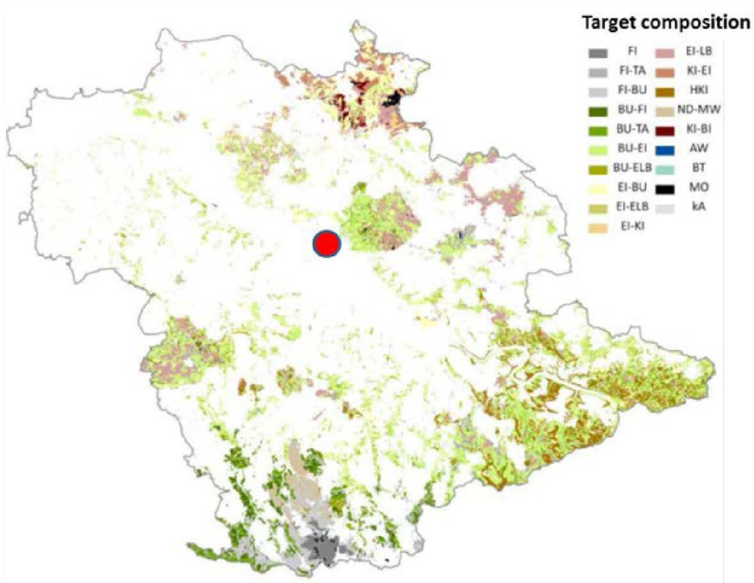


Source: REGKLAM 3.3.2a (2013e: 4, 12, 14)

Figure 8: Predicted drought and storm damage risks for Forestry

The choice of the tree species for regeneration is the probably the most important decision in forest management planning. Under consideration of the above presented scenarios for vegetation period and risks the optimal tree species for recommendation are identified (Fig. 9). The map shall support forestry owner, planner and manager in their decision-making.

The predicted climate change will change side conditions towards lower precipitation and higher temperatures. This shift will suppress vitality of the widely planted spruce (Picea abies), the most important and the most profitable timber tree of the region, and will bring it to its physiological limits. Apart of much lower performance the increasing calamities like bark beetles, crown breaks due to heavy loads of wet snow (snow-break), fungi or storm throws might cause economic failures. The recommended strategy is to establish spots of adopted, climate resilient tree species within the spruce mono-plantations now, to have dispersed sources of seed available in future times of crisis. The map of target forest composition (Fig. 10), based on ecological side factors, guide the identification of the species for the enrichment planting.



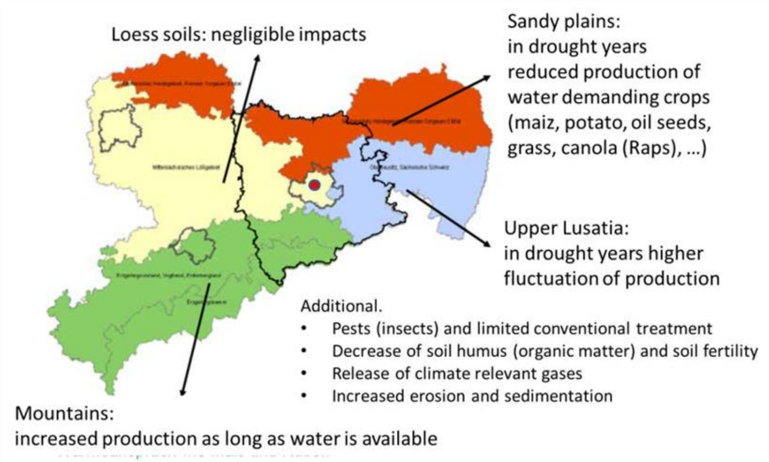
Source: REGKLAM 3.3.2c (2011: 12)

Figure 9: Scenario for ecological optimal future stocking

3.3 Agriculture

The changed ecological conditions affect agriculture as well as forests. The predicted trends will rather limit the future options on sandy soils and in the lower altitudes, esp. in the eastern parts, while the higher lands of the Ore Mountains might become a bit more productive due to the higher temperatures, as long as water is not limited (Fig. 10).

Due to the short-term production character of agriculture, with high flexibility in changing crop species and practices, climate change adaptation can be realized by the combination of a variety of adaptation measures. The range of adjustment options include: variation in planting material, crop rotation, soil cultivation, erosion control measures, fertilization, pest management, irrigation, alternative cultivation methods, and insurances (REGKLAM P3.3.1e 2013c).



Source: under use of REGKLAM P3.3.1e (2013c: 8) and REGKLAM (2013:19 ff)

Figure 10: Predicted impacts of climate change on agricultural production in Saxony

3.4 Health and urban planning[*]

The climate scenarios identified more extreme heat-events, which are defined as situations when maximum temperature >= 30 °C. Such temperatures are common in the tropics, for a temperate region like Saxony they mark an extreme. Especially larger urban areas will suffer due to the heat island effect, where the radiation is heating up the mineral surfaces of buildings and pavements, and the city buildings are blocking airflow and by this preventing natural cooling effects. Thermic stress might reach > 41 °C.

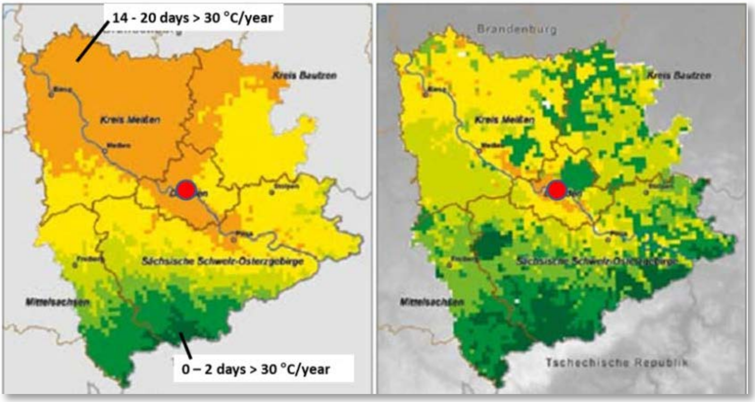
Heat waves reduce wellbeing of citizens and affect their health; a significant higher mortality is for heat events recorded. Heat events also promote concentrations of pollutants in the ground level atmosphere, esp. fine dust particles > 10 µm – PM10 and troposphere ozone, causing additional stress on humans. As practiced, mass media informs the public about danger and extreme heat events.

[*] Under use of SLfULG (2014: 95 ff., 116 ff.), and REGKLAM (2013b:17)

Predicted scenarios with higher temperatures and heat waves will cause higher water stress for urban green; the scenarios predict also increase cooling (energy) demand in summer, while a decreasing heating (energy) demand in winter is expected.

The modified precipitation patterns with more extreme rain events in summer will also increase the risk of flood. This is a thread for settlements close to embanked and canalized rivers, especially since substantial parts of the river's retention areas are converted to settlement and/or agriculture. Recommendation is to construct artificial retention areas and to increase the capacity of the sewage system to swallow the water masses from heavy rains in catchment areas.

The today's urban "mainstream" buildings in Saxony lack of heat protection elements like shutters, ACs, shade roofs, etc. Future designs of buildings have to be done under consideration of cooling and heating aspects. Apart from recommended constructive protection of buildings, vegetation is highly effective in buffering the heat effects due to shading, converting radiation energy into biomass by photosynthesis, and by evaporation. Urban and peri-urban vegetation is a highly recommended mean to suppress extreme heat and deliver many valuable by-services like amenity, recreation, phsycho hygiene and positive inspiration, biodiversity, air humidity etc. for the citizens. The various types of urban vegetation (trees, gardens, lanes, amenity plants on buildings) are summarized under "green space", they deliver a beneficial cooling service. The highest rate of cooling is achieved by forests (up to 6 °C suppression), the smallest by isolated urban green elements, because here the heating effect from buildings compensates the vegetation's cooling largely. Fig. 11 displays two-year 2045 scenarios for annual hot days (> 30 °C) in Dresden region, one without vegetation cooling effect (left) and with vegetation cooling effect. Recommendation is to increase and maintain larger areas of green space, esp. in functional connections to urban areas.



Colors show the number of annual hot days (> 30 °C) period 2044 – 2046, increasing from green to orange; left: without vegetation cooling contribution; right: with vegetation cooling contribution. Source: SLfULG 2014: 115

Figure 11: Cooling contribution of vegetation

Larger and connected green spaces cool more effective, and for aeration of cities, "green" corridors are designed to facilitate airflow from peri-urban forests to the inner cities. The suggested corridors for Dresden (Fig. 12) show multifunctional green spaces (in Fig. 12 dark green), including peri-urban forests and parks, and connecting corridors (in Fig. 12 light green). Urban planning has to consider air exchange (wind corridors) to prepare for the predicted climate change.

3.5 Climate change mitigation

As climate change *mitigation* measure the Saxonian state established a policy for increasing the share of renewable energy from 15% in 2010 up to 30% until 2020. Priority is given to wind as source, followed by biomass, photovoltaic, water and dumping side-gas (REGKLAM P3.3.1f 2013d: 7).

4. Discussion

Both projects provide sophisticated scenarios for future climate evolvement of the region, including variations in their severity. There are many detailed adaptation measures given, as expert solutions

Source: REGKLAM 3.2.2 (2013b: 17)

Figure 12: Vision of multifunctional green space and corridor-network design for Dresden

describing the current best practice of the sectors. This collection is a good service for practitioners and decision makers on the different levels as well as for interested laymen.

The recommendations given for the forestry sector are of a long-term nature, led by the optimization of the ecological requirements of the trees. Some of the instruments are innovative and can facilitate adaptation of forest planning efficiently. Nevertheless, under current market conditions there will be a significant trade-off between species demanded by the timber market and the future stocking. Here the managers have to decide carefully between business opportunity and cost of risks prevention.

The project's reports implicit that a technocratic top-down approach was employed. While various non-academic but public institutions have participated, the participation of private organizations or persons in the research is not so clear (for outsiders). This leads to the critical question if CCA can be done effectively without people affected. For example, the forestry sector, is it enough to tell a private forest owner based on a computer simulation that she/he has to change the currently profitable species to limit some of the future risk, or is it needed to give the owner the chance to do the analysis and evaluation on its own? Even if knowledge is provided, it needs also trust that this knowledge is proven and the best option for the individual's personal set of goals. It is not only the recommended adaptation option that could be modified by participating local people, also the participants, the local people will be changed by the process of analyzing and discussing scenarios and possible options to react.

Each of the sectors developed its set of recommendations. It would have been interesting to harmonize the recommendations between the sectors and to see the conflicts and synergies appearing on the higher level.

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Historical Path of Forestry and the Role of 'Ujamaa' Ideology to Today's Policy of Community Forest Management in Tanzania

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Abstract

Tanzania was colonized by the Germany in the late 19th century, and after World War II the United Nations put it under British mandatory. Later on in 1961, the country got her independence and adopted the capitalistic economy. Through the Arusha Declaration in 1967, it abandoned the capitalistic and adopted a socialistic policy to guide her socio-economic development. This policy was named 'Ujamaa' (family-hood) because it had more emphasis on African socialism cooperation. Socialism was pursued by Julius K. Nyerere who was the first president of Tanzania. This review explored the forest management path from pre-colonial period to the today's regime where community forest is a main concept. It was adopted by the Tanzanian forest policies of 1998 and revised in 2012. The study revealed that colonialism and introduction of Christianity diluted the traditional systems that were used by most communities for management of forests. During Ujamaa and resettlement of isolated rural populations in central villages more forests were cleared to meet immediate wood demands. Rural dwellers lost control of their traditional land and lost lives due to diseases and wild animals. Despite these shortfalls, socialism/Ujamaa created a platform for better forest management through political stability, decentralized governance and decreased levels of forest-based resources dependency especially for food and medicines. Forests managed under Ujamaa village governments had better conditions than the rest of forests. Ujamaa was the basis for community resource management of today. The first policy with community participation concept was enacted in 1998 and the forest sector was the pioneer of this. Consequently, we can conclude that, together with external

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influence, Ujamaa formed a basis for Participatory Forest Management (PFM) in Tanzania.

Keywords: forest resources management, socialism/Ujamaa, community based forest management, Tanzania, villagilization

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1. Introduction

Tanzania that was a British colony got her independence in 1961 and adopted the capitalistic economy. However, through the Arusha Declaration in 1967, the country adopted a socialistic policy to guide her socio-economic development (Kihiyo and Isinika 1998, Mbeyale and Merok 2005). This policy was named 'Ujamaa' (family-hood) by Nyerere, J.K the first president and founder of the country. According to Nyerere, the name 'Ujamaa' emphasizes the Africanness social type of relationship among individuals. The aim of Ujamaa was to make the people and country self-reliant through a combination of traditional values of cooperation with Western socialism. Ujamaa concept, entailed putting people into central 'communes' to create access to state education and medical facilities, and to make collective farming, based on the Chinese model, possible (Kilaini 1997, Ritho 2003). After resettlement people lived together to foster their own development and thus creating sense of communal ownership of the natural resources including forests. Forests that most people rely on for their daily livelihoods were recognized by the Arusha declaration and nationalized. The government, through the Forest Division owned all the forests and wood-based industries.

After declaring the Ujamaa policy, the government decided to organize for common settlement for rural Tanzanians. For the first time the policy of Ujamaa vijijini which meant establishment of villages 'villagelisation'[*] in the rural areas was implemented between 1970 and 1975. About ten million people were forced to move in common settlements/villages (Kilaini 1997). This is because Nyerere believed development could be

[*]Villagelisation in Tanzanian context implies both existing definitions: 1. the concentration of the population in villages as opposed to scattered settlements (in Africa and Asia). 2. The transfer of land to the communal control of villagers

attained by people (social welfare) and not material things (e.g buildings, cars and other assets) that these people could develop themselves after they had settled. In his book, Nyerere (1973) said, "It is particularly important that we should now understand the connection between freedom, development, and discipline, because our national policy of creating socialist villages throughout the rural areas depends upon it. For we have known for a very long time that development had to go on in the rural areas, and that this required co-operative activities by the people". It was believed that once an agricultural basis was formed industrial development would follow.

While Nyerere (1968) advocated on Ujamaa policy in the country there had been different views on the advantage and disadvantage of socialistic policy adoption and implementation on the forest-based resources as well as on the general welfare of the communities in the rural. This paper therefore aims at analyzing long term possible impact of Ujamaa on forest based natural resources in Tanzania. Specifically, the study would like to highlight on the role of Ujamaa policy for the today's adopted participatory approach on the management of these vital resources. The participatory policy approach is under the Participatory Forest Management framework which has two wings; one where the property is solely owned and managed by the communities named after Community Based Forest Management (CBFM) and the second, Joint Forest Management (JFM) where the state owned forests are jointly managed by the government bodies in collaboration with nearby communities.

2. Methods and approach

2.1 Country's profile

Tanzania is one of the three East African States in Africa. It is a republic government formed from the Union between Tanganyika and Zanzibar (Unguja and Pemba Islands in the Indian Ocean) in 1964. The country borders the Indian Ocean to the east with about 800 km shoreline. To the north are Uganda and Kenya; to the west, Burundi, Rwanda, and Congo; and to the south it borders Mozambique, Zambia, and Malawi (Figure 1). It has an area of about 945,087 km^2 and is inhabited by about 120 ethnic tribes with different cultures and language (URT 2002). The population by 2012 is estimated to be 40 million (NBS 2012). The country is endowed with a wide range of natural resources, including forests, wildlife, mountains, valleys and water bodies. Tanzania contains three of Africa's best-known lakes: Victoria, Tanganyika and Nyasa. Mount Kilimanjaro in the north with 5,895 m makes the highest point in the continent.

Source: CIA (2007).

Figure 1: Map of Tanzania showing neighboring countries.

2.2 Methods for data collection

This study was conducted through literature review and discussions with staff and other professionals at Sokoine University of Agriculture, Institute of Tropical Forestry at Tharandt in Dresden and in the Ministry of Natural Resources in Tanzania. The ministry officials were contacted for clarification and inputs in some areas. Analysis of the collected information was done using Content Data Analysis techniques. This method/tool allows summarization and critique of text (Krippendorff 1980) or wordy information in a systematic and replicable way, to make results more clear and 'meaningful' rich by explicit rules of data coding (Berelson 1952, Stemler 2001 and GAO 1996, Weber 1990).

3. Historical review of the forest management before and just after independence

3.1 Pre-colonial to colonial era forest management

Forests in Tanzania, as for many areas of Africa, were managed by traditional norms and ethics prior to colonialism (Biggeli et al. 2003, Gerden and Mtallo 1990, Ylhaisi 2000). These systems where strong enough to make everyone in the society to obey due to the attached beliefs and norms. The mandate and powers to ensure implementation certain rules and regulations were over the clan elders. There were little or negligible destructions on forests and general environment as a result of anthropogenic activities probably due to low human populations (Iddi 2002). But also these communities used the forest for subsistence activities e.g. for ceremonial activities, rituals ornamentals songs and general traditional dances.

It is postulated that forests and woodlands were managed differently depending on the ethnic group needs and beliefs but also depending on the vegetation/ecological function of the forest itself (Ylhaisi 2006). However, there is not much information available on how forests were managed during this time except few observations during the slave trade (Kajembe and Malimbwi 1996, Sluyter 2002). For example, when colonialism came in Tanzania, demand for wood including firewood and timber increased and sometimes shortage of wood was reported on the central route where slaves were being transported (Koponen 1988). As the result commercial harvesting started in some forests including those protected by traditional systems because intruders did not fear taboos.

Colonialism and introduction of Christianity observed a new era of culture destruction that slightly started to change the ‘respect’ people towards forests and their resources. Hence, deterioration of biodiversity started to emerge in some highly populated areas that raised concern for conservation measures. Therefore, this was the beginning of formal and centralized management systems especially on mountains slopes, lowland and coastal areas. During 19th century, colonial governments gazetted protected areas for wildlife and water catchment forests. In 1953, the first forest policy was formulated (Kessy 1998, WWF 2007) to give direction on optimal forest management in the country.

3.2 The onset of Ujamaa policy and its impact to colonial and traditional rules

As for most countries in tropics, the colonial period in Tanzania represented the formation and imposition of centralized management institutions for nearly all of the key resources found in governance terms (Kallonga et al. 2003). It was during the colonial period when a number of national parks and forest reserves were established across the country especially during German control before and soon after the World War I (FAO 2000a). The situation continued to exist until when the country got its independence and went into Ujamaa policy.

The main aspect of Ujamaa concentrated on the dismantling of ethnic boundaries and alteration of traditional or colonial political structures to create room for modern state villages (Mbeyale and Merok 2005). The objective was to give all Tanzanians in a one-political party state opportunity to participate freely and actively to their nation development as well as their own development. Unfortunately, most of the established natural resource reservations and impositions during colonial era remained the same. For example, the forest policy formulated during British colonialism in 1953 was adopted until 1998 when a new policy came in place (Kihiyo and Isinika 1998).

3.3 The successes of socialism/Ujamaa and its implication on participatory forest management

During colonialism, the rural population settled in small groups with some hiding deep in forest and probably in more remote areas to shy away from colonial administration. Post-colonial government in Tanzania adopted some structures of the colonial administration (Sheridan 2004). This attempt did not favor national unity neither did it create peace in the country. The society was segregated based on tribes, location, their cooperation to colonial rulers and control of natural resources. Introduction of Ujamaa ideology focused on creating a national unity beginning at basic levels (Nyerere 1968, Paul et al. 1986, von Freyhold 1979). People from different ethnic groups and small settlements were forced to move into common settlements where a new life began with the available resources (Kjekshus 1977).

Production of goods was done communally on common lands in a self-reliance motto (Guggenberger et al. 1989). The whole community shared everything that produced (Kajembe and Monela 2000, Nyerere 1968). The whole community under the custodian of elders managed forests as well as other natural resources. Having peace in the country has ensured reasonable resource use. Experiences from other countries where political chaos has persisted shows high-level biodiversity loss and fragmentation. For example, the existing conflicts in DR Congo and Rwanda has led to grave concerns for the mountain gorillas following latest inexplicable killings (UN 2007). If peace did not exist in Tanzania with her over 120 different ethnic groups, enormous resources could fall vulnerable to some irregularities and hence degradation.

3.4 The role of Ujamaa policy in the today's participatory approach framework

Setting of Ujamaa villages was the beginning of decentralization process in the country after the first trial during British colonialism (Mukandala 1998). Decentralization aimed at giving or sending more power to local authorities and agencies rather than the central government to work on day-to-day issues of the people's welfare in economy political and social aspects (Ng'ethe 1998). Therefore, villages received a great roll in management of natural resources including forests (Kajembe 1994). As a way to recognizing the role of local institutions in resource management a number of acts and regulations were enacted in the process (Oyugi 1988, Odera 2004). This included reforming of the Land Act, Village Act, and Election Acts so as to give local authorities more powers and democracy from the central government (Mniwasa and Shauri 2001, Iddi 2002).

Socialism in its way provided a unique democratization process to the people (Kikula and Christiansson 2000) as it was the focus of socialism to let the villages to work without much interferences from the central government or from the ruling party (Nyerere 1968). Therefore, according to Fairhead and Leach (1995) and Sluyther (2002) the ignorance of former governments on the importance of community-managed areas to biodiversity sustainability was revised. The rules and regulations have assisted in resource use conflict resolutions between societies and between villages that has long assisted in ensuring proper use of the resources.

Since forests were managed by local authorities, villagers felt that they had right to protect them. As the result, they provided manpower and protection that the government could not afford to guard them regularly. Therefore, it can be speculated that forests changed to regenerate especially in areas where degradation had occurred. Three decades after Ujamaa policy declaration, the control over forest harvesting has continued to be under village governments (Ostrom

1996, Wily and Dewees 2001, WWF 2007). The village governments have mandate to set out rules that defines appropriation and provisions that reflects good governance of forests. Some studies have shown that village forests and forests managed by villages have better conditions than central government managed forests or common land forests (Kajembe et al. 2003, NAFORMA 2015).

Therefore, villagelisation “finds a more acceptable and more workable management regime of forest resource” (Wily 2001). Today, most forests are managed participatory either being under Joint Forest Management (JFM) or under Community Based Forest Management (CBFM), which are well structured and instituted under the devolution of powers during Ujamaa process (FAO 2000, Iddi 2002, Wily and Dewees 2001). Experience from Babati District where community forest management started during active days of Ujamaa shows that villagers have become the de facto controllers and managers of forests that the new Forest Policy recognizes the importance of local people in taking full control of their forest resources.

4. Conclusion

Adoption of Socialism ideology in Tanzania was the beginning of the new life style amongst rural populations that had been used to live isolated, independent or in small groups. The national economy has received a drift shift and has been controlled in a more democratic way. Failures observed in the course of its implementation were somehow of short term and could not outweigh the benefits incurred by the people, the government and the environment. Generally, forest resources were better managed during socialism than ever before during ‘undefined’ mode of production practiced by colonial and post-colonial governments. Socialism gave people more mandates to plan and use at the lower level. Introduction of community forestry today in different forms like JFM and CBFM diffuse well in the decentralized systems of socialism as the government loses control towards sustainable management through centralized practices.

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Contribution of the National Adaptation Plan of Action Project to Sustainable Livelihoods in North Kordofan State, Sudan

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Abstract
Climate Change is recognized as a critical challenge to ecological health, human well-being and future development. Sudan has good agricultural potential, but variations in rain intensity and distributions with frequent drought cycles represent a serious risk confronting sustainable agricultural productivity and sustainable livelihood. The objective of this study was to investigate the role of the National Adaptation Plan of Action (NAPA) Project in enhancing the sustainable livelihood of farmers and pastoralists in North Kordofan State – Sudan under climate change and variability. Data was collected from primary and secondary sources. The primary data was collected from the stakeholders (farmers and pastoralists), using face-to-face interviews during the closing workshop of the project. A self-administered questionnaire was used to collect data from the project staff (focal persons of the project at North Kordofan State) and government officials for validation of findings. The main findings of this study are as follows: the state is vulnerable to climate change that creates difficult conditions for growing food, raising livestock and living. Land quality and productivity are strongly influenced by climate change and sites become highly degraded as asserted by the entire interviewed sample. Accordingly, ecosystems and biodiversity habitat changed due to overexploitation. Other effects of climate change, as perceived by the respondents include poor rural economies and poor food security (76.4%), land degradation (62%), poor human health (42%) and conflicts (29.7%). The main activities tackled by the project were awareness raising, capacity building, identification of vulnerable systems, and identification of the urgent and priority adaptation needs. The criteria led to the selection of urgent

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projects that contribute to adaptation of local communities to be prepared for climate change through a participatory and consultative approach, and aim at improving the adaptive capacity. The main projects proposed by primary stakeholders in the state are conservation of the environment, biodiversity, and conservation of rangelands, rehabilitation of gum gardens, and development of the Gurdud soils, improve fodder production to reduce conflicts, review and define new animal routes to reduce conflicts. The major adaptation activities identified in the state are community-based forest, rangeland management and rehabilitation. Additionally they concern replacement of household goat herds with sheep herds to reduce pressure on fragile rangelands; lessening of pressure on local forests through use of mud brick building design and alternative energy sources, land use conversion from agricultural activities to livestock raising, introduction of drought-resistant seed varieties, and afforestation of areas denuded of trees for building construction and firewood. The main conclusion drawn from the study is the fact that, if the local people are mobilized and sensitized in the proper way, using participatory methods in the presence of technical support, they can adapt well to climate change and variability.

Keywords: climate change, livelihood adaptation, rangelands, land use

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1. Introduction

Climate change is increasingly recognized as a critical challenge to ecological health, human well-being and future development. The biggest challenge in confronting the negative impacts of climate change lies in the developing world where people and systems are most vulnerable like in the case of the Sudan where the vegetation zones shifted southward, related to an alarming deforestation trend, coupled with fluctuating and sporadic rainfall, and frequent droughts beside other external shocks (Leary et al., 2008a). An important element in understanding vulnerabilities to climate change is linking current and projected exposures to climate stresses with exposures to other stresses and conditions that are responsible for hardship and low levels of economic welfare. People have developed ways of earning livelihoods and supplying their needs for food, water, shelter and other goods and services that are adapted to the climates of the areas in which they live, but the climate is ever more variable and deviations that are too far from the norm can be disruptive and even hazardous (Leary et al., 2008b).

On the southern edge of the Sahara Desert and lying within Africa's arid zone, North Kordofan State provides extremely difficult conditions for growing food, raising livestock and living. Water is lifeblood to people living in a regularly drought-stricken North Kordofan State. Sixty percent of the state's population of 1.4 million is constantly faced with nagging doubts about whether the rains will come and if they will have enough food to survive in each year (GoS, 2007). Drought is a regular phenomenon to the region. Declining rainfall over recent years has led to low production of crops, which makes households vulnerable to food crisis. When there is a good production season, farmers often need technical know-how on food processing and storage facilities to help overcome supply problems in poor growing years (Sanjak, 2004; Fadl El Moula, 2007).

Sudan is burdened with low human and economic development, serious environmental problems, and a high degree of vulnerability to current climatic variability. Its major environmental problems are deforestation, overgrazing, soil erosion, and desertification. At the same time, it is a country of significant resource potential, richly varied geography, and tremendous human capability. While in certain respects, the country is quite exposed to the potential impacts of climate change, it simultaneously undertake proactive steps that can preempt certain negative impacts, mitigate others, and enable the country to adapt to a changing climate (GoS, 2007). This rich geographical diversity also means that some of Sudan's ecological zones are confined to small areas, with human communities, flora, and fauna highly adapted to subsist within them. Other zones are vast, supporting large shares of the country's agricultural production. For both types of areas, climate change poses a major threat. Under changing climatic conditions, adverse changes in the distribution and productivity of Sudan's natural resources – its forests, soils, grasslands, surface waters – are expected to have significant repercussions for millions of people (Osman et al., 2008).

In recent years, Sudan has made significant development strides, yet profound poverty and other challenges persist. Factors such as life expectancy (56 years), school enrollment (34%), and GDP per capita purchasing power parity ($1,797/year) combine to place Sudan in the low human development category of the UNDP (2002). Traditional subsistence agriculture dominates the Sudanese economy, with over 80% of the population dependent upon crop production and/or livestock husbandry to support their livelihoods. Agriculture accounts for nearly half of GDP, and is responsible for the vast majority of employment. While the country is highly dependent on the agricultural sector for income, foreign currency, and food security, the sector is dominated by small-scale farmers who employ largely rain-fed and traditional practices – those render Sudan highly vulnerable to climate variability (as seen during past persistent droughts), and to anticipated climate change (Sanjak, 2000).

2. National adaptation plan of action project

In response to environmental challenges, Sudan has been actively seeking to promote domestic sustainable development policies, by engaging in international environmental processes, facilitating strategic research, employing preventive measures and monitoring mechanisms, enabling ground-level development work, and strengthening its human and institutional capacity (GoS, 2007). Sudan is presently engaged in a range of projects and processes that support a sustainable development trajectory. Yet, Sudan's vulnerability to climate change threatens to jeopardize such efforts. Climate scenario analyses conducted as part of the preparation of Sudan's First National Communications indicate that average temperatures are expected to rise significantly relative to baseline expectations. Projections of rainfall under climate change conditions also show sharp deviations from baseline expectations, with decreases of about 6 mm/month during the rainy season (Zakieldeen, 2007). In addition, temperature is expected to increase. Such a rise in average temperatures and drop in annual rainfall will affect the viability of current agricultural productions systems and the efficacy of current water resource management strategies, while at the same time they are endangering public health. As such, climate change poses serious challenges to Sudan's overriding development priorities in agriculture, forestry, water resource management, and energy development. Adaptation-related activities that build upon existing national processes, forge new linkages where possible, break new grounds where needed, and have the potential to lessen this climatic vulnerability. The National Adaptation Program of Action (NAPA) process, and the scoping, consultation and prioritization processes offer a framework for enabling the necessary adaptation actions.

Intentionally the United Nation Framework Convention on Climate Change (UNFCCC) became an UN agreement where countries are invited to reduce risks of climate change. Sudan has ratified the UNFCCC in 1993 and other related protocols and developed the national adaptation plan. The Higher Council for Environment and Natural Resources (HCENR) is working as implementing agency at federal level with relevant institutions at state level. The NAPA goals are to build state adaptive capacity and integrate climate change in policies and plans. The HCENR conducts and coordinates activities related to climate change, biological diversity, and national environmental initiatives. The Ministry of Environment and Physical Development supervises environmental policy integration into national development policy, has regulatory oversight of policy implementation (i.e., standards and sanctions), and coordinates environmental activities across governmental and non-governmental organizations. The process leading to the submission of Sudan's First National Communication (FNC) was carried out by three operational entities: the Project Steering Committee, the Technical Committee, and the Project Management Team. Sudan's HCENR established a state focal point and a technical committee of experts from related government ministries, research, academia and farmer's unions. The committee was trained to build its capacity and learned by doing. It achieved data collection, vulnerability assessment, hot spots mapping, and identification and prioritization of community adaptation initiatives. Many workshops were held at federal and state level to develop the process and communication network at federal and state level to assist the process (Zakieldeen, 2007).

3. Objective of NAPA project

Key vulnerabilities in the country include agriculture sector, water sector, livestock, forestry sector, infrastructure and settlement, as well as health sectors. Due to financial constraints, in the beginning NAPA focused on agriculture, water and health sectors only, and in the end on agriculture and water resources sectors.

The primary goal of the NAPA process is to communicate broadly to the international community priority activities that address Sudan's urgent needs for adapting to the adverse impacts of climate change. To achieve its goal, the following specific objectives were pursued: i) to ensure adequate stakeholder representation; ii) to identify a comprehensive range of climate change adaptation strategies; iii) to establish country-driven criteria to evaluate and prioritize adaptation measures; iv) to make consensus-based recommendations for adaptation activities; and as needed, to recommend capacity building, and policy programs, and institutional integration, as part of adaptation priority activities.

4. Objective of the research

The overall goal of the case study is to investigate the contribution of the NAPA project in North Kordofan State to enhance the resilience of farmers and pastoralists in the state, and to show that NAPA interventions in agriculture and water sectors operate as climate change adaptation options. The operational hypothesis of the case study is that NAPA project interventions can respond, on the ground to climate change adaptation needs for vulnerable groups (farmers and pastoralists).The project also aims to respond to this hypothesis by exploring the framework to assess the impact of the approach on community resilience.

5. Methodology

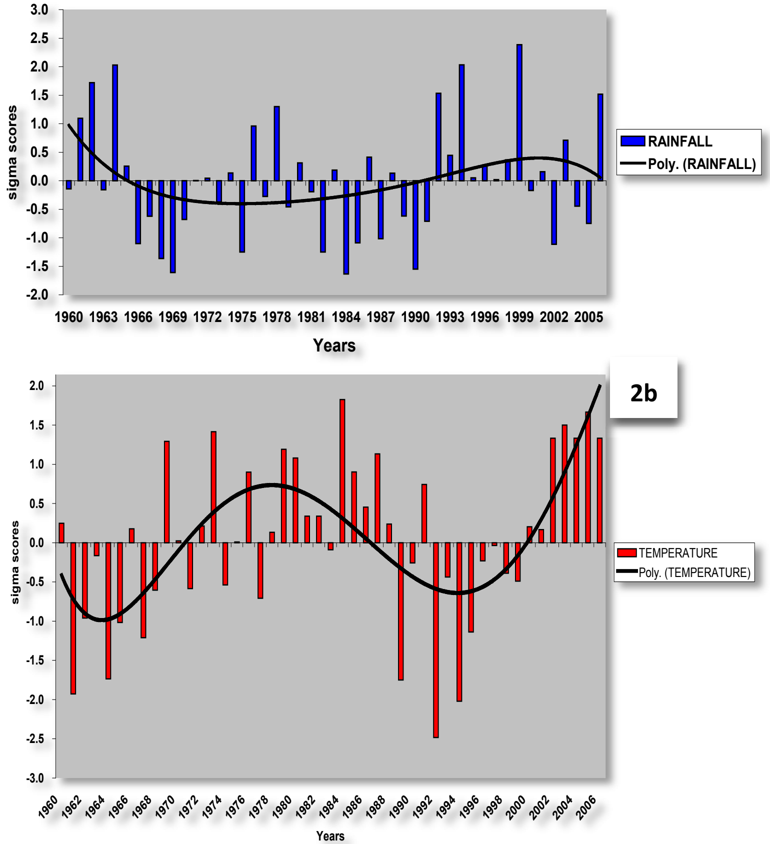
5.1 Study area

North Kordofan State (Fig. 1) is located in the west of Sudan and lies between latitude 12014' - 160 45' N and longitude 270 30'-420 22' E with an area of 190,840 km^2. Area of rangelands is 43,200 km^2,

Sudan (white) and North Kordofan (red). Source: www.en.wikipedia.org

Figure 1: Map of North Kordofan State

and the forest area is 96 km^2. The population of the state is 2,039,496 capita, 69% of which are rural. The economy of the state depends mainly on rain fed agriculture and gum Arabic production. Livestock herding covers 22.5 million heads. The traditional mining also contributes to the state economy. The soil is predominantly sandy covering 55% of the total area. The Gardod soil* represents 20 % and the clay and loamy soil represent 15 % and 10 %, respectively.



Source Fadl El Moula (2007)

Figure 2: Rainfall (2a) and temperature (2b) anomalies in El Obeid

2a

* Arenosol, low in nutrient and organic matter, with high sensitivity to erosion

There are four climate zones according to annual rainfall average, length of growing season and humid months. Desert zone (5% of state area), semi-desert zone (48%) arid zone (25%) and semi-arid zone (22%). The erratic rainfall and short growing season constitute a major risk to agriculture. Figure 2a (Fig. 2) shows annual rainfall anomalies and the trend at El Obeid (capital of the state), while Fig. 2b shows anomalies and the trend in temperature of the state.

5.2 Data collection

Data was collected from primary and secondary sources. Primary data was collected from primary stakeholders (farmers and pastoralists), using face-to-face interview during the closing workshop of the project. A questionnaire was used to collect data from the project staff (focal persons of the project at North Kordofan State) and government officials for validation of findings. The number of the primary stakeholders was 43 (23 pastoralists and 20 farmers), while the number of the secondary stakeholders was 12 from Ministry of Agriculture and Forests, North Kordofan State. The interviews were semi-structured where a series of open questions were asked, followed by more specific questions depending upon the responses to the open questions. Two data collectors were recruited from the Forests National Corporation, Khartoum. They were qualified and widely experienced extension officers. The evaluation process of NAPA Project in North Kordofan State focused on:

Processes:

- How NAPA built upon national capacity;
- How NAPA engaged actors and how they were prepared;
- How NAPA supported the preparation and implementation of NAPA priority projects.

Products:

- NAPA related outputs and consultative aspects of NAPA processes.

Catalytic effects:

- The ways NAPA project promoted the rate of adaptation and prioritization;

- How NAPA integrated and implemented climate change adaptation and related actions.

6. Results and discussion

6.1 Vulnerability of the state to climate change and variability

North Kordofan State is vulnerable to climate change and the most vulnerable areas are the localities in the northern part of the state (Bara, Gabrat Alsheikh and Sowdery localities). The main climatic factors prevalent at the study area are fluctuation of rainfall, uneven distribution of rains, frequent drought cycles, floods, and increase of temperature, winds and storms. These factors are responsible for conditions difficult for growing food, raising livestock and living. Agnew and Chappell (1999) confirmed that rainfall in Sudan is unreliable and the country is well known for its dual environmental problems of drought and desertification. Around 50% of the perceived periods of drought in the Sudan was meteorologically confirmed with rainfall well below average (Teklu et al., 1991). Moreover, the vulnerability of local communities is aggravated by non-climatic factors. The key informants asserted that some on the non-climatic factors are more determinant for the sustainable livelihood compared to climatic factors. The main non-climatic factors are the following: lack of a national sustainable development strategy for the state, acute poverty, conflicts and civil unrest, limited capacity of key ministries, legal and institutional weaknesses, increase of natural disasters, and energy insufficiency. This coincides with Global Humanitarian Forum (2009), showing that Sudan is considered most vulnerable to climate change, due to its overall vulnerability to drought. Another factor that increases the region's vulnerability is the strong dependence of its population on pastoralism and dry land agriculture, which is poorly developed.

Small-scale farmers dominate the agricultural sector. Typically, such farmers live in conditions of persistent poverty and rely on rain-fed and traditional practices. This combination renders them highly vulnerable to climate variability, as evidenced by the widespread suffering in rural areas during past droughts. Indeed, chronic drought is one of the most important climate risks facing Sudan (Ibrahim, 1983). Pastoral and nomadic groups in the semi-arid area of the state are also affected by climate change and variability that ultimately lead to conflicts. Most of the natural resource base conflicts in the country are associated with climate change and variability. This is in line with Moon (2007), showing that among the vehemently debated impacts of climate change is its causal link with conflict, as is the case with all resource based conflicts. Analyzing the Darfur crisis, some went to the extent of stating that the real culprit is climate change. The eradication of poverty through improved agricultural production is among Sudan's primary development objectives. Poverty is deeply entrenched in rural areas. Sudan's diverse agro-ecological zones and abundant surface water offers the potential to produce a range of crops, as well as livestock. Yet, production remaining consistently quite low, which in large parts is due to an agricultural system that is not well adapted to rainfall variability and prolonged drought events (Hamed, 1971). Table 1 shows the principal climatic factors challenging the main productive sectors in North Kordofan State.

Table 1: Impacts of climatic factors on main sectors of North Kordofan State

Sector	Climatic Factors	Impact
Agriculture Pastoralism Forestry	- Shortage of rainy season - Uneven rain distribution - Drought cycle - Floods - Increase of temperature - Wind and storms	- Crop season failure (insecurity) - Deterioration of rangelands - Deforestation - Mortality of tree seedlings (deforestation) - Increase of water requirement - Decrease of feed resources (fodder) - Pest and diseases infestation - Soil deterioration (degradation) - Formation of sand dunes - Poor rural economies and food insecurity
Water resources	- Shortage of rain - Drought - Heat increase - Wind storms	- Increase of water requirement - Decrease of agricultural production - Decreased water table - Lack of water resources

6.2 Adaptation options

Livelihoods in North Kordofan State are similar to those of Darfur. Both are closely linked with natural resources. Rural production systems are predominantly based on sedentary cultivation (farming) and transhumant and nomadic pastoralism. Historically, during past drought episodes, local people in the state managed to adapt their living systems through different strategies, for example, by diversifying their livelihood strategies, or by moving with livestock to fodder and water-rich areas, i.e. nomadic pastoralist migration from within the region to more distant areas and urban centers (Elasha-Osman and Sanjak, 2007; Elasha-Osman, 2008). Household mobility has also enabled adaptation to climate variability when core activities came under ecological pressure from drought.

The primary stakeholders adopted different coping mechanisms to enhance their resilience under evolving harsh conditions in North Kordofan State. Some of the coping mechanisms are autonomous (locally driven) and some others are adopted interventions. The primary stakeholders listed the main adaptation options for the agriculture sector like water harvesting techniques using terraces, shifting to early maturing crop varieties, agroforestry, and diversity of animal fodder. Regarding the water sector, the main adaptation options for the primary stakeholders, are water harvesting through construction of manmade depressions (haffir), boreholes and concrete basins. This coincides with Sanjak (2004) showing that traditional terraces are historical tools to mitigate the negative impacts of the erratic nature of rainfall in western Sudan. In the study area, there are different designs of terraces according to the financial possibilities of farmers and the type of soils.

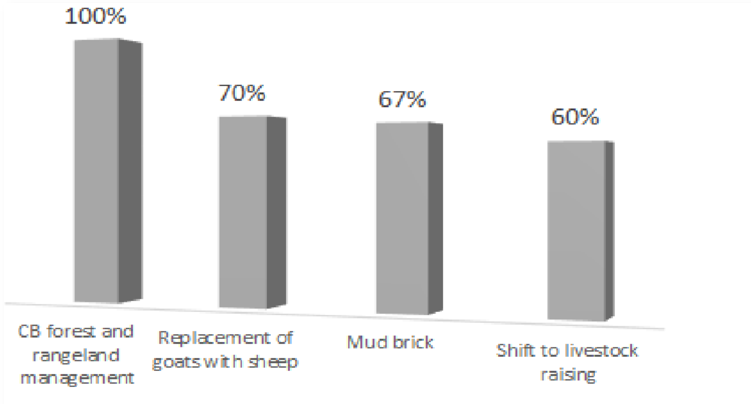
Based on a participatory consultation process involving the primary stakeholders, a number of projects were proposed for North Kordofan State. Implementation of these projects would enhance the resilience of local communities in the state. The proposed projects refer to protection of environment and biodiversity for conserving rangeland, rehabilitation of the Gum Arabic belt, development of the Gurdud soils, improvement of fodder production for the sake of reducing conflicts between pastoralists and settled farmers, livelihood alternatives for Graih El Sarhah area to adapt to climatic changes, and review and definition of new animal routes to reduce conflicts.

The criteria for the selection of the above-mentioned projects comprise improvement of the adaptive capacity, representation of urgent and immediate needs for the most vulnerable groups prepared through a participatory and consultative approach, improvement of communities' adaptive capacity, and removal development barriers caused by the impacts of climate change. Accordingly, the proposed activities of the project include the establishment of forests and grazing allotments, capacity building to manage natural resources, identification of vulnerable systems, awareness raising, management of rangeland, establishment of nurseries, sand dunes fixation, introduction of renewable energy sources, and adoption of mud building. In the final round, only one project was selected for implementation. The winning project is environmental conservation and biodiversity restoration in North Kordofan state as a coping mechanism for rangeland protection under conditions of increasing climate variability.

6.3 Perception of primary stakeholder on adaptation activities

There was no significant difference regarding adaptation activities proposed by the secondary stakeholders and the primary stakeholders. Fig. 3 shows the adaptation activities for climate change and variability as perceived by the primary stakeholders in North Kordofan State.

The entire interviewed sample of the primary stakeholders (farmers and pastoralists) asserted that community-based forest and rangeland management and rehabilitation is the most important adaptation option to climate change and variability in North Kordofan State. This finding is verified by the fact that the rains become sporadic in nature and contribute to the failure of the agricultural seasons. Accordingly, the respondents prefer to resort to animal husbandry at the expense of crop production. This finding coincides with Zakieldeen (2007) and Osman and Sanjak (2009), showing that reliance on animal husbandry contributed to the resilience of local people in the study area.



CB = community based

Figure 3: Adaptation activities in North Kordofan State

Reliance on sheep instead of goats that are the real menace to the vegetation cover led to restoration of natural rangelands in North Kordofan State. This finding is in line with respondents opinions where 70% accentuated that replacement of household goat herds with sheep herds is one of the vital options to cope with climate change and variability at the study area for the sake of reducing pressure on fragile rangelands and forests. About 67% respondents stated that adaptation option might be lessening pressure on local forests for provision of building poles through adoption of mud brick building and the use of alternative energy sources. Around 60% respondents believe that conversion of land use from agricultural activities to livestock raising is the most important adaptation method for climate change and variability.

7. Conclusion

The main conclusions drawn from this study comprise:

- NAPA project contributed to increasing awareness of the adaptation challenges that climate change poses;
- Some activities of NAPA priority projects identified address sectoral and cross-sectoral adaptation needs;

- Food security was the most prioritized sector followed by terrestrial ecosystems and water resources;
- Women need to be recognized as key stakeholders in consultations and decision-making.

8. Lessons learned

- Animal rearing on the expense of agricultural activities is the most convenient coping mechanisms to climate change and variability. Animal wealth contributes to the resilience of the local inhabitants to climate impacts through guarantying satisfactory animal products even in years of poor rainfall. Moreover, reliance on animal husbandry guarantees food security.
- North Kordofan State is no longer suitable for agricultural production due to the erratic nature of rains, frequent drought cycles and land degradation.
- The implementation of the project has the potentiality to contribute to the consolidation of the social fabric through the organization of farmers in implementing the project as a pilot project in the northern part of North Kordofan State.
- Fruitful results from the implementation of environmental conservation and biodiversity restoration in northern Kordofan State as a coping mechanism for rangeland protection under conditions of increasing climate variability needs developmental interventions that are flexible, agile and potentially fast-moving to respond to the changing environmental, social and demographic conditions of the study area.
- The northern part of North Kordofan State is no longer supporting farming production. The practical solution for this case is animal rearing and this needs to be genuinely considered in any future interventions for reduction of resource-based conflicts.
- There is a need to change the existing culture that encourages conflict into a culture that encourages peace; local customary potentials to do this exist.
- There is a need to make more explicitly the link between conflict and poverty in policy discussions and field activities. This link should inform future project activities and interventions.

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Local People's Perception of Climate Variability Including Their Mitigation and Adaptation Strategies in Mountainous Areas of Uganda

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Abstract

We examined the perceptions of local people towards climate variability including their mitigation and adaptation strategies to climate variability in the mountainous areas of Uganda, as they are one of the most prone areas to climate change effects in Uganda. The objectives of the study were to: (i) assess the awareness of climate variability amongst local people on Mt. Elgon, Uganda, (ii) document the mitigation and adaptation strategies to climate variability of the local people on Mt. Elgon, Uganda. This was done through conducting semi-structured interviews in Manafwa District that is located on the slopes of Mt. Elgon in Eastern Uganda. The data was analyzed using descriptive statistics. It was found that the majority of the local people were aware of the prevailing climate variability that they described in terms of increased variability in temperatures, rainfall amounts, droughts and floods. However, their level of knowledge of climate variability differed. Local people are implementing a number of mitigation and adaptation strategies, but the sustainability of those strategies is not known. It is therefore recommended that the sustainability of these measures be assessed in addition to furthering local people's understanding of climate change and their coping strategies.

Keywords: climate variability, mountains, Manafwa, Uganda

1. Introduction

Climate change related increase of climate variability is a major global problem threatening humans, as it is associated with a number of

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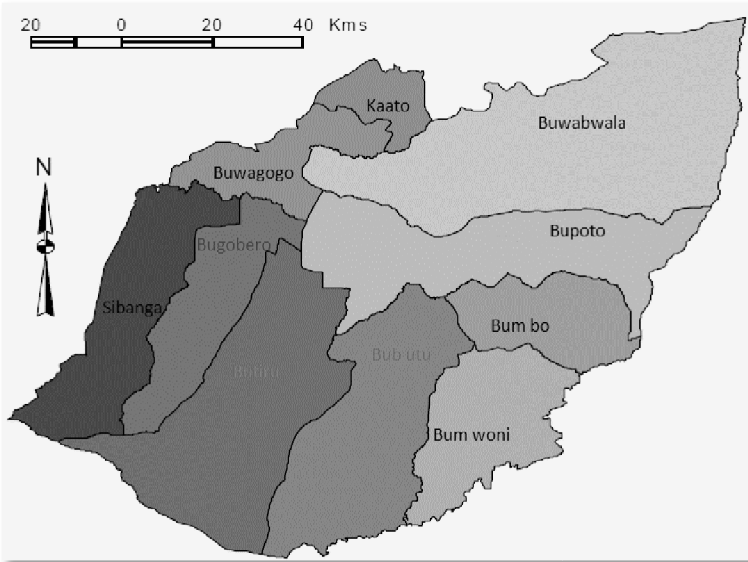
impacts. Uganda, a developing country located in East Africa covering an area of about 24.1 million hectares with a current population of about 33 million people (UBOS, 2011), is not an exception to climate change and its impacts. According to MWE (2013), one of the most vulnerable areas to climate variability in Uganda are the mountainous area, especially Mt. Elgon in Eastern Uganda and Mt. Rwenzori in Western Uganda. In Mt. Elgon, the population density is over 700 people per square kilometer. Since a huge proportion of Uganda's population lives below the poverty line and survives on about USD 1 per day thus being heavily dependent on natural resources (UBOS, 2011; NEMA, 2010) for basic livelihood needs, the majority of people in mountainous areas derives its livelihood from subsistence agriculture but also supplements it with resources obtained from the forested mountain ecosystems.

Despite the recognition of climate variability as a global threat to livelihoods especially in mountainous areas, there is still inadequate information about whether local people understand climate variability in addition to knowing how to mitigate and adapt to it. Hence, the overall objective of this study was to explore knowledge of climate change including its mitigation and adaptation strategies of the local people living in mountainous areas. The specific objectives were to: (i) assess the awareness of climate variability amongst local people on Mt. Elgon, and (ii) document the mitigation and adaptation strategies to climate variability of the local people. This study might play a vital role in shaping the agenda for local people's mitigation and adaptation to climate variability in mountainous areas.

2. Method

This study was conducted in Manafwa District located on the slopes of Mt. Elgon in Eastern Uganda. This area is characterized by high population densities that are heavily dependent on subsistence agriculture supplemented with forest resources from the forested mountain ecosystem for their livelihoods. The area was deemed appropriate for this study, as it has experienced climate related shocks like prolonged or reduced rainy seasons in addition to mud/landslides among other impacts.

Data collection was done through conducting semi-structured household surveys of 216 randomly selected households in the 18 sub-counties in Manafwa District (Fig. 1).



Source: RCDF (2010)

Figure 1: Sub-counties of Manafwa district in Uganda.

Questions were tailored to gathering information on households' understanding of climate variability and how they were dealing with it by focusing on the last 5-10 years. Data was analyzed using descriptive statistics in SPSS software package.

3. Results

3.1 Socio-economic characteristics of respondents

Table 1 shows the socioeconomic characteristics of the surveyed respondents in Manafwa District. The most of the respondents were between 21 and 40 years of age (44.4%), married (87.5%) with average annual income ranging between Uganda Shillings 100,000 to 500,000

(38.4%) while the respondents were not very proportionally different in gender with males constituting 55.5% while females were 44.5%.

Table 1. Socio-economic characteristics of respondents (n=216)

Characteristic of respondents		Frequency	%
Age (Years)	1-20	19	8.9
	21-40	96	44.4
	41-60	74	34.2
	>60	27	12.5
Gender	Male	120	55.5
	Female	96	44.5
Marital status	Single	3	1.4
	Married	189	87.5
	Separated	4	1.9
	Widowed	17	7.9
	Others	3	1.4
Average annual household incomes Uganda Shillings (UGX)*	<100,000	53	24.5
	100,000-500,000	83	38.4
	500,000-1,000,000	43	19.9
	>1,000,000	29	13.4
	Others	8	3.7

3.2 Local people's awareness of climate variability

Table 2 shows local people's awareness of climate variability in Manafwa District. Most of the respondents agreed that there was variability in climatic variables including rainfall amounts received, temperatures, length of wet season, length of dry season, frequency of droughts and frequency of floods in the last 5-10 years where the climatic variables have either increased or decreased. Most of the variability identified by the local people could be associated with negative impacts to their livelihoods. However, certain contradictions seemed to occur in knowledge of climate variability and these might be attributed to local variation in climate.

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* In USD, using an average exchange rate of 2,550 UGX/USD: 100,000 UGX = 39.21 USD, 500,000 UGX = 196.07 USD, 1,000,000 UGX = 392.15 USD

Table 2. Local people's awareness of climate variability

Variable	Trend	Frequency	Valid %
Rainfall amount received	**Increased**	**133**	**63.6**
	Same	12	5.7
	Decreased	58	27.8
	Not sure	6	2.9
Temperature	**Increased**	**84**	**42.4**
	Same	45	22.7
	Decreased	43	21.7
	Not sure	26	13.1
Length of wet season	**Increased**	**91**	**46.9**
	Same	25	12.9
	Decreased	57	29.4
	Not sure	21	10.8
Length of dry season	**Increased**	**104**	**53.3**
	Same	27	13.8
	Decreased	42	21.5
	Not sure	22	11.3
Frequency of droughts	**Increased**	**84**	**43.3**
	Same	24	12.4
	Decreased	63	32.5
	Not sure	23	11.9
Frequency of floods	**Increased**	**96**	**52.7**
	Same	19	10.4
	Decreased	22	12.1
	Not sure	45	24.7

3.2 Local people's perception of the causes of major observed trends

Table 3 shows the local people's perception of the causes of the major trends in climatic variability. The results revealed that local people attribute climate variability to many causes although the most frequently reported cause is deforestation and tree cutting. The ability of the local people to attribute climate variability to many causes could also be an indicator of their differing knowledge on climate variability.

Table 3. Local people's perception of the causes of the major trends in climatic variability

Characteristic	Presumed causes
Rainfall amount received	Deforestation and tree cutting
	Nature/Climate change/ weather change
	God's wish
	Geographical set up of the area
Temperature	Deforestation and tree cutting
	Climate/weather change
Length of wet season	Deforestation and tree cutting
	Climate/weather change
Length of dry season	Deforestation and tree cutting
	Reduced tree planting
Frequency of droughts	Deforestation and tree Cutting
	Poor farming methods
	Changing weather conditions /Climate change
Frequency of floods	Poor farming methods
	Too much rainfall
	Deforestation and tree cutting
	Changing weather conditions /climate change

3.4 Local people's mitigation and adaptation strategies to climate variability

The local people of Manafwa District revealed several mitigation and adaptation strategies to climate variability. They included among others: tree planting, especially Eucalyptus on the slopes, migration to other areas, adoption of agroforestry technologies and other farming practices, changes in crop varieties and planting seasons, adoption of short rotation crops and new technologies for drying crops, use of fertilizers and pesticides, increased reliance on credit facilities and community based organizations'/NGOs' help, and reliance on food reserves, food aid or food storage.

4. Conclusion and recommendations

This study was aimed at assessing local people's perception of climate variability including their mitigation and adaptation strategies in Mountainous areas of Uganda. It is concluded that the local people in mountainous areas of Uganda are knowledgeable about climate variability although there seems to be variations in their knowledge. The local people are also making tremendous endeavors to deal with climate variability as manifested by the presence of mitigation and adaptation strategies to the impacts of climate variability. However, it is not clear whether the mitigation and adaptation measures in place are sustainable considering the socio-economic set up of the local communities. It is therefore recommended that the sustainability of the mitigation and adaptation measures be assessed in addition to enhancing local people's understanding of climate change and how to deal with it.

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Role of Indigenous Knowledge in Traditional Farming System Management under Changing Climate, Sudan

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Abstract

This paper is about the utilization of indigenous knowledge in farm management practices under climate change in North Kordofan. The local population there has a long history with climate change hazards and effects, including droughts, desertification and flash floods; causing loss of livestock, failure of crops, food insecurity and famine. Consequently, community members have accumulated knowledge concerning weather related events. Data were collected in north Kordofan from three distinctive ecological zones (Enhud, Bara and Umrawaba), using a stratified simple random sampling technique with a sample size of 300 respondents. Results show that more than 60% of the target communities have experience with climate change, while 60% of have accumulated their climate knowledge through knowledge transfers from one generation to another. Indigenous knowledge for adapt to climate change include soil conservation, forest protection and animal herd management.

Keywords: climate, indigenous knowledge, traditional farm management

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1. Background and problem statement

Sudan is among the countries that are most vulnerable to climate change and climate variability in Africa, because the majority of its land is either arid or deserted (Zakieldeen, 2007). Furthermore, the country

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is suffering from poor infrastructure and technology; ecosystem degradation; complex disasters and conflicts. These in turn have negatively affected the population and weakened their adaptive capacity; hence, increasing their vulnerability to cope with climate change (Boko et al., 2007). The country has experienced several long and devastating droughts in the past. Besides droughts, Sudan also experienced extreme flooding events as the major climate-related hazards associated with climate change. Climatic changes have affected agriculture through their direct and indirect impact on crops, soils, and pests, which in turn affects food availability as a basic pillar of sustainable food security (Mahgoub, 2014). Farmers of Kordofan are considered as most vulnerable group to climate change and variability (Zakieldeen, 2007). They have a long history with climate change hazards that started since early 1970s including droughts, desertification and flash floods. Climate or weather events have resulted in devastating effects in rural communities in North Kordofan, including loss of livestock, failure of crops, food insecurity and famine (Ali, 2008). Consequently, the community members have accumulated knowledge concerning the weather related events and the expected outcomes. However, the role of such knowledge in coping with climate change and/or adaptation to climate change is not identified. This indigenous knowledge offers detailed information that adds to conventional science and environmental observations, as well as to a holistic understanding of environment, natural resources and culture. Therefore, the study aims to fill the knowledge gap in the role of indigenous knowledge in farm management and adaptation to climate change.

2. Research objectives

The overall objective is to identify the role of indigenous knowledge in farm management under climate change in Kordofan state. Specific objectives are:

1. To identify types and role of indigenous knowledge in land and soil conservation
2. To investigate the role of indigenous knowledge in cropping and agroforestry practices.

Research questions:

a. What types of indigenous knowledge exist and what are their roles in land conservation?

b. What are the roles of indigenous knowledge in improvement of cropping and agroforestry practices?

3. Methodology

Two types of data exist, secondary and primary data. Primary data: using structured questionnaires for three main sites representing three distinctive ecological zones (Elnuhud, Bara and Umrawaba) of Kordofan. Secondary data: reviewing literature (reports, internet, and previous studies). Simple random sampling with a sample size of 300 respondents (3%) was used. Measures of dispersion and central tendency were calculated to characterize the situation of climate change and the role of indigenous knowledge in managing climate risks.

4. Result and discussion

4.1 Farmers' perception of change in the amount of rain

The results (Table 1) showed that the majority of farmers have experienced drastic changes in the rainfall amount during the last twenty years. (60%) of farmers was perceived it as severe change.

Table 1: Farmer perception of change in the amount of rain

Rain amount, %		Evaluation to amount				Rain distribution, %		Evaluation regarding			
Changed	Not changed	Little	Average	Drastic	Not known	Changed	Not changed	Little	Average	Drastic	Not known
90.9	9.1	13.1	25.3	60.6	1.0	89.9	10.1	14.1	35.4	48.5	2.0

In addition, the majority (89.9%) of farmers have indicated that there was change in rainfall pattern and distribution and it was average to drastic change. The result illustrated that most of farmer's knowledge on climate change and variability comes from knowledge transfers from relatives and personal experiences. Access to climate information and knowledge from extension is poor where only 36% of the respondents have access to extension (Table 2). In conclusion, farmers are aware what is happening around either from their own experience or through knowledge share among relatives.

Table 2: Farmer climate change source of knowledge

Climate source of knowledge			Access to extension	
Personal observation and experience, %	NGOs, %	Relatives, %	Available, %	Not available, %
31.7	4.1	64.2	36.5	63.5

4.2 Climate impact and farmer coping strategy

The majority (84.8%) of farmer perceived (Fig 1) that climate change in the last two decades has adverse effect on crops productivity and led to outbreak of new pests and diseases that negatively affect the farm performance (Fig. 1). To overcome or to reduce the adverse effects

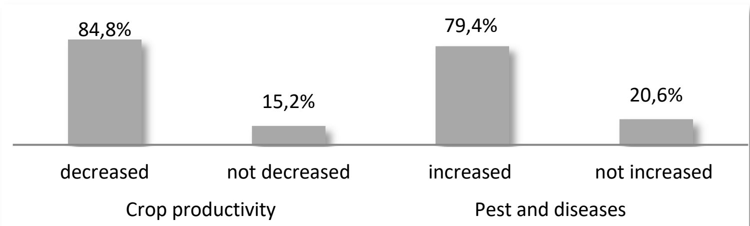

Figure 1: Farmers' perception about climate impact on farm performance

of climate change and its consequences in farm productivity and ultimately in the farm output and in the household's living, farmers have developed and adopted some coping strategies (Fig. 2) among which are change of sowing timing, change of crops and increase of cultivated area.

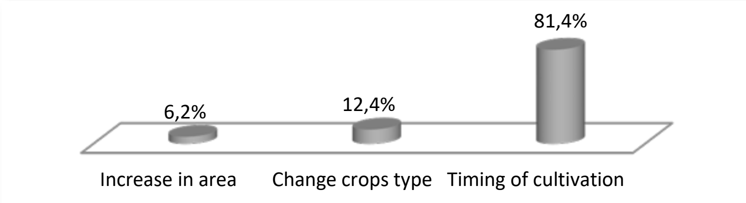

Figure 2: Farmers' coping strategy in face of climate change

4.3 Farming practices under climate change

Farmers have been found aware of the problems of soil degradation and have traditionally been conservation minded at the level of the farm. Farmer indigenous knowledge with regard to land conservation is found to include cut and carry system, zero tillage, growing of local landraces. Other research has indicated those farmers are using their knowledge to manage soil fertility through manure application, bunds, crop residues, crop rotation and cover crops, gradual terrace building for degraded farm plots, controlled soil burning, trash line and grass and vegetation strip (Mulat, 2013).

Table 3: Knowledge and method application for soil conservation

Knowledge of conservation methods		Application of indigenous knowledge in soil conservation	
Have knowledge	Not have	Apply	Not apply
67.5	32.5	63.2	36.8

Table 4: Type and rank of application of soil conservation methods

	Check dam	Terracing	Shifting culti-vation	Crop rotation	Plant residues	Animal manure
First rank	92.9	22.2	50.0	87.2	17.6	0
Second rank	7.1	66.7	50.0	10.3	17.6	40.0
Third rank		11.1	0	2.5	64.8	60.0
Total	100	100	100	100	100	100

Results showed that more than 60% of the farmers have knowledge and apply methods of soil conservation (Table 4). With methods of

conservation of check dams (93%) and following of crops rotation (87.2%) rank at the top followed by terracing (66.7%) and shifting cultivation (50%) with leaving of plant residues (17%) and application of animal manure come last.

4.4 Integrated farm practices

Previous research has explored that indigenous cropping practices is contributing to a better supply of fiber through enhancing the production capacity of the ecosystem via reduced drought effect and sequestering of carbon. Multiple or inter-cropping is indigenous practice on croplands. Farmers usually allocate their land to multiple crops either in the same time or for a long period to enable them being harvested at different times of a year or as a coping mechanism against the effect of diseases, insect pest or drought. In addition to that, the practice itself is important for soil fertility improvement, increasing yield and ensuring income in time of disaster.

Agriculture is the main occupation of the 80% sedentary population in the region. Most livelihood activities and few crops dominate, and these are often a mix of staple (millet and sorghum) and cash crops (groundnut and sesame) and integration of hashab trees (*Acacia senegal*). Indigenous agroforestry often occurs at homesteads. On such plot of land, one can find various crops and trees of different species. Indigenous trees are very important for farmers as they serve as source of fruit and other non-timber products, shade, fuel wood, and to the ecosystem as source of moisture and as source of animal feed. Indigenous agroforestry is considered to play a vital role in enhancing the productive capacity of the ecosystem and can be used as tool for food supply diversity and hence reduce the effect of famine and drought by regulating micro-climate, sequestering carbon in the soil and has significant role in adaptation to climate change (Shiferaw, 2011). In the study area, more than half of farmers (Table 5) adopted plantation of trees in their farmlands in order to protect land, generate income, secure forage for their small ruminants and increase crops yields. It is clear from the results; although the majority (64.3%) of the communities has not common forestland, the individual farmer's overtime was able to accumulate and share knowledge about the role of trees in protection of farmland in addition to other economics benefits.

Table 5: Farmers' perception of benefits from integration of tree and agroforestry practices

Growing of trees (%)		Availability of common forest (%)		Farmer perception of growing trees' benefits (%)			
Applied	Not applied	Available	Not available	Land protection	Forage	Increase productivity	Income sources
57.1	42.9	35.7	64.3	33.3	22.2	13.3	31.1

4.5 Impact of indigenous practices on farm productivity:

The results showed that farmers' indigenous practices have positive impacts on crops productivity, with differences range between 1.0% for chickpea as minor crops and 34.7% for groundnut as major cash crop. The test for mean difference among farmers has shown significant differences in all crops under level of significance of 0.01 (Tab. 6 and 7).

Table 6: Productivity difference between groups of farmers applying and not applying indigenous practices

	Apply	Not apply	Percentage
Millet	2.6783	1.8743	30.0
Sorghum	2.4572	1.9416	21.0
Chickpea	1.9000	1.8818	1.0
Sesame	2.5841	2.4750	4.4
Groundnut	4.0000	2.6115	34.7
Roselle	3.0000	1.9650	34.5

Table 7: One-sample test for crop yield

	t	df	Sig. (2-tailed)	Mean difference	95% Confidence interval of the difference	
					Lower	Upper
Millet	9.313	41	0.000	2.41190	1.8889	2.9349
Sorghum	8.408	35	0.000	2.17139	1.6471	2.6957
Chickpea	4.250	4	0.013	1.74000	0.6034	2.8766
Sesame	5.576	13	0.000	2.81071	1.7217	3.8998
Groundnut	4.029	5	0.010	2.83333	1.0258	4.6409
Roselle	6.905	9	0.000	2.29500	1.5431	3.0469

5. Conclusion

Many farmers have adopted plantation of trees in their farmland in order to protect land, generate income, secure forage for their small ruminants and increase crops yields. Overtime, individual farmers have accumulated and shared knowledge about the role of trees in protection of farmland in addition to other economics benefits. Farmers are found to be aware and applying soil conservations methods through the experience they learn from relatives or they gain throughout their lives. The indigenous practices of farmers in traditional farming of North Kordofan have positive impact on crop yield and contribute to sustainable system management.

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Quarterly Climate Change Preparedness Workshop in Arsi Negelle, Ethiopia

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Abstract

Quarterly climate change preparedness workshops were carried out in Arsi Negelle district of Oromia Region of Ethiopia since 2011. Their main objective was to present the seasonal weather forecasts to farmers and relevant stakeholders, in order to assess the ways in which the local people interpret and use the weather forecast for the next season of sowing, planting, crop harvesting, storing and marketing. The series of workshops undertaken with the local stakeholders served as a platform for sharing weather forecasts and compare with local climate monitoring results, as well as for assessing their relevance and accuracy. Further, the interplay between household vulnerability, forest conservation and forest access was assessed. The quarterly climate change preparedness workshop involved participants of eight Kebeles (peasant association). In addition, a district administrator/representative, and representatives from the department of agriculture and meteorological agency, development agents including Ethiopian team research members have participated in the workshops. Within the Kebele households have varying capabilities and entitlements, based on characteristics like gender, clan affiliation, forest-based income. Most farmers expressed experiences regarding climate variability and change. They perceived an increase in temperature, a prolongation of drought periods, a decrease in precipitation amount and undependable patterns of rainfall.

Keywords: Arsi Negelle, dry and rainy seasons, precipitation, variability, weather forecast

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1. Introduction

As natural resources are reduced in size and composition due to the changing climatic conditions, communities living in and around the resources respond usually through shifting cultivation and adapt themselves to rapidly changing social, economic and policy conditions. The communities tend to adapt to the emerging changes and exploit the available resources in new ways as markets develop. We carried out quarterly climate change preparedness workshops since 2011 with the main objective to present the seasonal weather forecasts to farmers and relevant stakeholders in order to assess the ways in which the local people interpret and use the weather forecast for the next season of sowing, planting, crop harvesting, storing and marketing. The series of workshops undertaken with the local stakeholders also served as a platform for comparing the weather forecasts with local climate monitoring results, as well as for assessing their relevance and accuracy.

During the discussions with the various stakeholders, emphasis was put on how climate change plays a role on ecological, social and political factors of the Arsi Negelle district. The workshop was a central event in the participatory action research process that aims to foster an adaptive learning of farmers, district administrators, experts, development agents and PhD research process. Furthermore, based on the four major weather stations of the study area, climatic information was downscaled and presented during the quarterly climate change preparedness workshops that is usually held following farmer's production calendar. This has also been serving as a platform for reporting and discussing past forecasts and compare with local climate monitoring results, assess their relevance and accuracy in order to provide farmers an opportunity to reflect on their adaptation strategies.

The quarterly climate change preparedness workshop involved participants of eight Kebeles (peasant association). In addition, a district administrator/representative, and representatives from the department of agriculture and meteorological agency, development agents and Ethiopian Mechal team members have participated in the workshops. The stakeholders also examined the interplay between household vulnerability, forest conservation and access. Within the Kebele, individual households have varying capabilities and entitlements, based on some characteristics like gender and clan affiliation that rely on forest-based incomes in different ways. Most of the farmers expressed experiences regarding climate variability and change. They perceived an increase in temperature and elongation of drought periods. They also revealed a decrease in precipitation amount and further pointed out that undependable patterns of rainfall are prevalent in the district; where rainfall is erratic, poorly distributed, and often of high intensity.

The successive quarterly workshops were conducted from February 2011 to May 2014 in Arsi Negelle district by involving the farming communities representing approximately about 320,000 individuals. The communities live surrounding the Arsi Forest and Wildlife Enterprise (AFWE) that produces forest products for the urban markets and supports the local livelihoods of the communities in providing construction materials, fuel wood use and sale, permanent employment for some, and daily labor opportunities for the poor living in the vicinity of the forest.

2. The process

2.1 How the objectives shifted through time

Each workshop started with a summary presented and discussed in the previous workshop and feedback of the previous quarterly weather condition forecast. The objectives of the first workshop were: to introduce the project to the community and other stakeholders, to understand farmers perception level regarding the problem, to understand these indicators of climate change and local coping mechanisms, to share existing information and experiences, and also to identify entry points for future interventions for successful implementation of the Mechal project. Moreover, the objectives of the second workshop were to provide farmers with quarterly weather information for their locality so that they make proper decisions with regard to their farming activities. The intention was to assess the level of understanding and trust that farmers have in the weather forecast data regarding Arsi Negelle district. Later on, the stakeholders examined and discussed the deviations between their observations of the weather situation in Arsi Negelle and the weather data forecasted for the same area in a particular season (short and main rainy seasons, spring and dry seasons). The objective of the third workshop was to provide farmers and other stakeholders with periodically updated and essential weather information and knowledge that minimizes or prevents losses caused by extreme and unpredictable weather conditions. Moreover, the fourth workshop was designed to understand how farmers assess impacts of weather forecast and apply in their day-to-day farming practices activities according to their local condition, in Arsi Negelle areas. During a workshop, the upcoming main rainy season (June, July, August and September) and reports of passed small rainy season (February, March, April) are outlined and feedback is obtained from the stakeholders. As a result, the climate assessment report of both the small rainy season and the climate outlook of the summer season will be presented, discussed, and important lessons drawn. The weather forecast for dry season will be made that helps farmers to harvest and store their agricultural products timely. The three specific objectives of the fifth workshop were to discuss and get feedback on the outcomes of the previous main rainy season forecast, to provide the quarterly weather forecast about the upcoming dry season (October to January), and to have additional discussions on various related issues.

As primary stakeholders, farmers were selected from different Kebeles, the lowest level of administration in Ethiopia. Twenty four farmers attended the presentation representing eight peasant associations selected for this purpose. Moreover, eight development agents from the selected eight peasant associations, ten experts and officers from relevant offices, two experts from the Ethiopian meteorological agency, Hawassa branch, and all the Ethiopian Mechal team members and project administrators participated. Discussions such as spatial and temporal rainfall distribution were carried out during the workshops. Women participants/farmers who were not participating in the previous workshops were included in the fourth and fifth quarterly workshop meetings.

The farmers represented the major agro-ecological zones of the district namely, Kolla (lowland), Woina dega (mid altitude), and Dega (highland). In addition, Development Agents (DAs), district administrator and experts were included. Higher officials from the Arsi-Bale Forest and Wildlife Enterprise as well as from the Woreda Agricultural Development Department (WADD) were involved. Besides, an expert from National Meteorological Agency (NMA) Awassa office was represented. Moreover, Mechal project team members (researchers, project administrator, MSc and PhD students) took part at the events (Koelle and Annecke, 2013; quarterly workshop I-VII minutes).

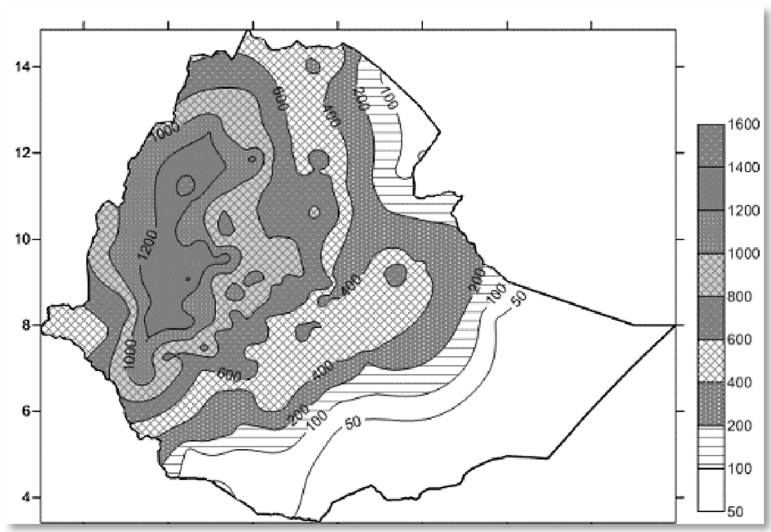
2.2 Logistics

In preparation of each workshop, the district forest and natural resources experts as well as development agents contacted farmers and other stakeholders. The dates of the meeting were arranged and communicated to the district experts by the Mechal coordinator in Ethiopia and his team members. The district expert/s informed the development agents when the quarterly workshop was going to be conducted. The seasonal weather forecasts were presented using Microsoft Power Point to show what was happening and what may happen in future. The presentations were done by the representative from the Ethiopian Meteorological Agency in Hawassa. The workshop venue was the assembly hall of AFWE that was used for presentation, discussion and feedback, free of charge due to the good relationships between the Mechal team members and the district officials including the enterprise authorities. The workshop was seen as an important tool to involve the farmers in climate variability discussions and a mechanism of finding ways to cope with the climate variability effects. At the end of each workshop, a modest daily allowance was paid to participants to cover transport (fuel costs for those who used their vehicle) and refreshment costs.

2.3 Process of a typical workshop

A typical workshop was carried out after the participants registered or the registration was sometimes accomplished parallel to the presentation (Mechal, 2011a, 2011b, 2011c, 2013, 2014). After completing registration, Mechal project coordinator, welcomed participants and made a brief speech about the workshop. He reiterated the general objectives of the quarterly workshops and pointed out the objective of the current workshop. Then after, he invited the district administrator, or the manager of Arsi Forest and Wildlife Enterprise, to make an opening remark. Sometimes representatives were invited to make a speech or additional remarks on behalf of the district administrator or enterprise manager. All of the opening speeches were made in Afan Oromo, the language spoken by the participants. Although most of the remarks were translated using translator, some parts were not fully translated due to some terminologies/phrases such as 'La Nina phase of ENSO prevails globally' or 'El Nino', or 'rainfall performance in analogue years', which may limit complete understanding of the messages (Oettle et al., 2014). Hence, it is made sure that full translation of the presentations in the next workshops would enhance clear understanding of issues by all participants including those who do not understand Afan Oromo. Sometimes Amharic (national) language is used to clear things that were not very clear.

After the remarks, an expert from the meteorological agency, presented the quarterly climate assessment report for the past main



During main rainy season, rainfall maximum concentrates along western part of Ethiopia where it rains every day. Low rainfall and less number of rainy days are present over the northeastern lowlands and peripheries of the southern lowlands.
Source: Seasonal weather forecast map, Ethiopian Meteorology Agency (2015)

Figure 1. Weather forecast for the main rainy season 2011

rainy season (June to September) and the forecast for the coming dry season (October to January). The main points of his presentation are as follows.

The expert started his presentation by reminding what the forecast was for the previous main rainy season. He recapped that the Kiremt season expected to enter following the normal/regular pattern while ending before the normal time. He further recalled that farmers were informed to select the right crop and plant in due time.

In his assessment report, he stated that most parts of the country including Arsi Negele experienced a regular pattern of the main rainy season both during onset and during cessation. Although such midterm assessment reports were disseminated to farmers and other stakeholders on time, he highlighted the difficulty of presenting such midterm reports to Mechal participants due to the fact that periodic workshops are conducted seasonally (Mechal, 2011a, 2011b, 2011c, 2013, 2014).

2.4. Data and climate prediction methods:

Data:

- Historical and real-time daily and monthly rain
- Historical and predicted ENSO and related indices
- Predicted oceanic and atmospheric systems
- Research findings
- Previous documents

Prediction methods:

- Simple and multivariate statistical techniques
- Spatial analysis
- Dynamical and physical interpretations
- Tele-connection approaches

2.5 Farmers' perception on climate change and variability

Furthermore, questions such as what was farmers' perception on climate variability and change were raised. The discussions with farmers indicated that the ability to perceive climate change is a key precondition for their choice to adapt. The perception level and experiences of the community with regard to climate variability and change were found to vary based on the agroecology where the respondents came from and on their socio-economic backgrounds. Despite the variation, however, they all exhibited that they perceived variability and change in climatic features of the district.

In addition, they explained the impacts of prolonged drought on human, livestock, woodland, soil, resources and described how their livelihoods are threatened by it. The other factors mentioned were problems related to flood and soil erosion. As the rains usually fall after long dry periods, they destroyed field crops and products. Besides, they characterized the problem as recurrent phenomena.

2.6 What were the indicators of climate variability and change?

The other point of discussion on which farmers reflected their experience was the various traditional ways used as indicators to sense and predict climate variability and change in the Arsi Negelle district. The followings were mentioned as commonly used indicators of climate variability and change:

- When certain tree species such as *Podocarpus sp*. (zigba) sprout shoots (pseudo leaves and branches) during the dry period, it indicates that there will be elongation/extension of the dry period;
- When such species like *Podocarpus sp*. spread dusts from twigs and branches, it indicates that the rain period is coming soon;
- When there is a frequent wind mainly in the afternoon, it is an indicator of drought;
- Warmer days and cooler nights also signal drought;
- Delayed rain accompanied by sporadic rain after a long dry period entails no water infiltration, leading to too much runoff.

2.7 Who is more vulnerable?

Identification of the vulnerable social group and ecosystem resources is important for designing an effective and efficient intervention in the area. To that end, farmers were asked to identify the vulnerable system and social groups in the area. They identified the lowland (Kolla) kebeles are more vulnerable to climate variability and change mainly because they are already water stressed, and constraints related to alternative livelihood engagements exacerbate the problem and limit their adaptive capacity. It is also noted that in some cases, the highland is more affected than the lowland, especially during intense rainy seasons. In such cases, crops in the lowlands benefit more and perform better.

Furthermore, in Arsi Negele district livestock, especially cattle, are found to be more vulnerable. According to the discussion, this is attributed mainly to shortage of water and feed. Among the community groups, elders, women and children are identified to be more vulnerable to existing and future climate variability and change.

2.8 How communities share agro-meteorological and market information?

The information is shared through officers/experts, development agents, friends, radio and the quarterly workshops. In the district, agro-meteorological and other related information (market, risk, etc.) are shared based on the traditional system established since long time ago. They described it as *our father's way* of information transfer. In this approach, farmers from highland kebeles share information with their lowland counterparts and vice versa. In most cases, the highland and lowland kebeles are tied with marriage alliance and social relationships. Hence, they use those networks and relationships for information exchange. Besides, some of the farmers confirmed the use of formal media, mainly radio, in the district. The workshop participants were multipliers or trainers for the broader group of farmers. The involvement of the various stakeholders was seen as an important subject for the exit strategy, in which the climate change preparedness workshop will be continued by the district authorities involving local people in weather forecast discussions after the phase out of the Mechal project.

2.9 Existing coping/adaptation strategies used by communities

The adaptation strategy may depend on many socio-economic and biophysical factors which in one way or another affect the adaptive capacity of the community. Previously, Arsi Negelle was known as sorghum producing area. Here changes were made in crop diversification due to improved inputs and climate change impacts.

3. Implementation

Once farmers exchange and come across such agro-meteorological information, the next question was how they incorporate/use it in their activities. Even though the use of information depends on its nature, generally, farmers use it during fieldwork and field preparation (early preparation of fields and applying agricultural inputs), selection of early maturing crop varieties, and early sowing are common practices. In case of elongated and untimely rainfall, they use the information for early storage of crops. Sometimes, they may also make a decision to sell some of the less productive livestock or temporarily move them to some other places with better forages and water sources.

3.1 Limitations of the workshops

There were some noise and disturbances during discussion due to various reasons (registration, per diem, and latecomers). Language barrier (tendency to summarize and adjust what has been said by the community) by the interpreters from Amharic to Oromifa and vice versa was seen as a limiting factor. There were limited number of workshop participants due to available space and resources. Getting quarterly forecasts from the National Meteorological Agency of Ethiopia caused some delays but key issues were addressed. Differences in internet connectivity between some colleagues in Ethiopia and other members of the team have been a hindrance to regular and effective communication.

3.2 The positive side of the workshop

All workshops were participatory, ideas and suggestions were accepted any time. Discussion and knowledge sharing with one another and with academics and other service providers were successful. Researchers, PhD and MSc students' participation in the processes of quarterly workshops was educative (learning from farmers) and enriching in experiences for working with local people in their studies, and building lasting relationships. The workshop information and knowledge gained from the workshop were shared and disseminated with other fellow farmers who were not able to participate in the workshops.

4. Lessons learnt

Quarterly workshops enabled interaction with farmers as part of the PAR approach of the project, which is more time consuming than a purely extractive data gathering approach. Working closely with the main stakeholders in the Arsi Negelle district has helped to facilitate the basis for the exit strategy of the Mechal project in Ethiopia. When working with farmers, one has to be patient, respectful and friendly at all times no matter where, i.e., on the road accidentally, during meetings and research undertakings when dealing with research related issues. One has to bear in mind that the researchers are using farmers' time for answering questions prepared to extract qualitative or quantitative data. Farmers need to be informed well ahead of time when and where such activities are to be carried out.

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Impact of Farmer Field Schools in Diffusion of Information about Climate Change in South Kordofan State, Sudan

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Abstract

This study was conducted in South Kordofan State, Sudan. The main objective of this research is to study the role of Farmer Field Schools (FFSs) in diffusing information about climate change among rural farmers. The specific objectives are to find out the appropriate approaches used, to explore the respondents' perception towards FFSs and to what extent the beneficiaries benefited from FFS. Primary quantitative data was collected from field surveys using structured questionnaires (in-depth and repeated interviews). Seventy-five respondents (members of FFSs) were randomly selected. The results show that more than half of respondents were literate (58.7%). FFSs organized field days, demonstration plots, and group discussions (25.3%, 9.6%, and 37.3%) to deliver knowledge. The majority of participants perceived the performance of FFSs as very good (54.6%), 82.6% of beneficiaries indicated that their farm productivity increased due to improved skills in agricultural practices, and 26.7% acquired knowledge about climate change effects. Finally, the study recommended that more FFS should be conducted in the areas that are vulnerable to climate change and displacement.

Keywords: Farmer Field School, information diffusion, Sudanese farmers, climate change impacts

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1. Introduction

Agricultural extension plays an important role in the development of agriculture. The ultimate objective of extension is to promote the spiritual, mental and social growth of farmers and their families. Extension methods are some of the tools used to introduce and disseminate latest technology in the farming communities. It is now well known that the traditional extension methods such as classroom training or training and visit system are not very effective in implementing agricultural information packages. In rural communities of Kordofan, awareness about new technologies was created through the efforts of Extension Department and NGOs (Ahmad et al. 2007). Participatory agricultural platforms, such as farmer research teams and farmer field schools (FFSs), offer the potential for change that goes far beyond agriculture (Humphries et al. 2012). The FFS approach is self-propagating, inexpensive, and an extremely efficient way of extending agricultural knowledge in countries like Sudan. The FFS has one of the most impressive track records in participatory community approaches (van den Berg and Knols 2006). The main objective of FFS is to help farmers to become experts in their field through weekly field training sessions, on farm research, demonstration plots, and nurseries. Information generated from different sources should reach the intended users and ultimately meet their needs. Variations in the information needs of rural farmers in South Kordofan have been demonstrated (Elizabeth 2007). A key to reducing uncertainties is an improved understanding of the contributions of individual factors (Lobell and Burke 2008). Potential impact of FFS goes beyond the process of innovation and addresses challenges of farming systems.

2. Objectives

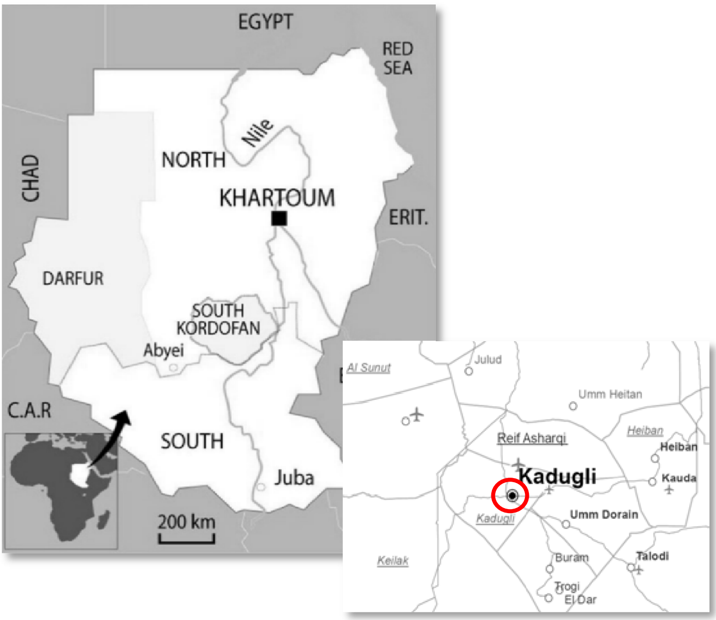
The overall objective of this study is to analyze the role of Farmer Field Schools in diffusing agricultural awareness among vulnerable rural farmers in the study area. Specific objectives are:

1. To identify methods FFSs used in delivering extension messages to fill knowledge gap concerning climate events and impacts;
2. To know farmers' perceptions toward the performance of FFSs;

3. To analyze to what extent the beneficiaries benefited from FFSs installed in the area.

3. Study area

South Kordofan State neighbors North Kordofan State from the north, Republic of South Sudan from the south, White Nile State from the east and West Kordofan State from the west. Its population is around 1,206,404 persons. The State covers an area of 970,470 km^2 (MCA 2008). Livelihood activities found in the area are agro-pastoralism and nomadic pastoralism.



Administrative map of Southern Kordofan. Source: www.thenewstribe.com, 2011

Figure 1: Location of the study area within South Kordofan State

A large livestock population, including cattle, sheep, goats and camels, representing about 30% of the national livestock, characterizes the area. Rain-fed farming, both for subsistence needs and commercial operations, is practiced in the area. Rainfall is adequate and there are extensive plains of clay soil. A third source of livelihood is derived from the natural forests in form of collecting fuel wood, building material, gum Arabic and fruits from various trees (UNDP 2006).

4. Data collection and analysis

Three Farmer Field Schools (FFSs) were established in the area of Eltaba, Kodugly and Dameik. Each farmer field school included 25 farmers. A list of participants involved in extension activities of FFSs was obtained from IFADs Manager. The list comprised 75 farmers. An interview schedule was prepared for the collection of the required data. It was pre-tested, irrelevant questions were deleted, while relevant questions were modified and added. For the purpose of convenience, the researcher interviewed respondents, mostly at their respective village organizations. The data collected was edited and transferred to tally sheets to facilitate its processing, tabulation and percentages. Simple statistical techniques like averages and percentages were used for the discussion and interpretation of data, and Chi-square test was applied.

4.1 Measurement of some of the theoretical concepts

- Farmers' education: measured by the number of years of formal education completed by the farmer.
- Contact with extension agent: the total number of contacts the farmers had with the extension agent either by visiting the extension office or the visits made by the extension agent to the farmers, either individually or in-group.
- Climate change awareness: measured by the total number of environmental problems mentioned by the farmers. Each environmental problem (e.g. deforestation, drought, desertification, flooding, etc.) mentioned by the farmer was given a score of one.
- Farmers' cosmopolitanisms: measured by the total number of visits to any city that the farmer had made during the last year.
- Social participation: measured by the total number of social organizations in which the respondents was a member, the number of offices the respondent took in, and the number of voluntary activities (e.g. building of schools, mosques, nafir for helping others, etc.), in which the respondents participated during the last year.

5. Results and discussion

Findings revealed that 41.3% of the respondents were illiterate (Table 1). Since illiterate farmers are less innovative than their literate fellows, this high rate of respondents with no formal education is expected to represent a major constraint to disseminate knowledge to farmers concerning climate change impacts in farming systems.

Table 1: Educational level of the respondents

Educational level	Frequency	Percentage
Illiterate	31	41.3
Primary	24	32.0
Middle	12	16.0
University	8	10.7
Total	**75**	**100**

Source: Field survey, 2014

Agricultural extension is considered as informal adult education enabling farmers to benefit from available agricultural technologies and improved practices. Methods used in FFSs were trainings, field days, demonstration plots, and group discussion (Table 2).

Table 2: Approaches mostly used by extension agent

Type of informal education	Frequency	Percentage
Trainings (learning by doing)	21	28.0
Field days	19	25.3
Group discussion	28	37.3
Demonstration plot	7	9.4
Total	**75**	**100**

Source: Field survey, 2014

The majority of participating farmers saw the FFSs performance as very good for the rural community (54.6 %), while 36% thought it was good and needed improvement, and 9.3% thought it was inadequate (Table 3).

Table 3: Respondent's perception towards Farmer Field Schools

Farmers' perception	Frequency	Percentage
Very good performance	31	41.3
Good and need for	24	32.0
Improvement	12	16.0
Inadequate in our area	8	10.7
Total	**75**	**100**

Source: Field survey, 2014

Results revealed that the majority of beneficiaries (52%) favored to have their yields increased, 21.3% to have acquired social skills, while 26.7% to have acquired knowledge about climate change effects (Table 4).

Table 4: Respondent's favored benefits from Farmer Field Schools

FFS benefits	Frequency	Percentage
Yield improvement	31	41.3
Acquired social skills	24	32.0
Iclimate change awareness	12	16.0
Total	**75**	**100**

Source: Field survey, 2014

Results of Chi-square test showed that there was a significant correlation between the farmers' innovativeness and education level, contacts with extension agents, climate change awareness, farmers' cosmopolitanisms and social participation (Table 5).

Table 5: Chi-square test

Dependent	Independent variables	No.	%	Sig.
Farmers' innovativeness	Education	44	58.7	0.043
	Contact with extension agent	70	93.3	
	Climate change awareness	20	26.7	
	Farmer's cosmopolitanisms	31	41.3	
	Social participation	16	21.3	

Source: Field survey, 2014. Significant if 0.05 or less

6. Conclusion and recommendations

The Farmer Field School proved that extension follows partly the well-known proverb "seeing is believing" in transferring improved technology, know-how and do-how to the respondent farmers. Especially the active participation of trainees in group discussions and *learning by doing* in trainings effectively count for 65% of the methods employed by the FFS.

The education level plays a vital role in understanding, application and utilization of extension education, as well as for maximization of accruing benefits. The tools of message delivering used by extension agents to introduce and disseminate latest technology and information in the farming communities have significant effects to make farmers innovative. This research work endorses the effectiveness of farmer field schools. Therefore, the study recommends that more FFSs should be conducted in vulnerable areas to bridge the gap of climatic events. Further studies will implement and refine present data toward a better understanding of the role of FFSs to provide knowledge for increasing productivity and climate change effects.

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Effects of Climate Change on Traditional Rain-fed Agriculture in Sheikan Locality, North Kordofan State, Sudan

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Abstract

The study focused on the climate change, its effects on traditional agriculture, and strategies to cope with it in Sheikan locality during the period 1976-2005. The study depended on statistical, historical and regional approaches. Data was collected via interviews, observation and questionnaire. The sample comprised 150 farmers, representing 2% of all farmers in the area, identified by simple random sampling. Data analysis depended on criteria and mean deviation, besides linear regression equation and correlation coefficient. The study revealed that population increase affects traditional agriculture by decreasing the production of “Makhamas” (0.42ha) in sorghum, down to less than 2 sacks (66.7% of respondents). Signs of climate change are rainfall, low soil fertility and others (67%, 28% and 5%, respectively). Strategies to cope with climate change are dry farming (Ramail), mentioned by 62% of the respondents and use of crops suitable for the higher temperature (65%). Recommendations include more meteorology stations, large-scale agricultural extension and adoption of surface water harvesting techniques.

Keywords: climate change, rain-fed agriculture, sorghum, North Kordofan, population increase

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1. Introduction

Sudan, one of the least developed countries, is vulnerable to climate change because of both Sudan depends economically on natural resources, and Sudan's inhabitants show a low adaptive capacity. Most of the land in Sudan is quite sensitive to changes in temperature and precipitation (Zakieldeen, 2007). The Sudanese agriculture is based on three types of farming systems: i) traditional, ii) mechanized rainfed, and iii) irrigated (Sassi, 2012). Accordingly, the latter two sectors contribute to the production of the majority (76%) of staple foods like millet and sorghum. The prevailing climate condition induced damage to these crops.

The unreliable nature of rainfall, together with its concentration in the short growing seasons, heightens the vulnerability of Sudan's rain-fed agricultural systems. Mean annual temperatures vary between 26 ^{o}C and 32 ^{o}C across the country. The most extreme temperatures are found in the far north, where summer temperatures can exceed 43 ^{o}C (Fadel-El Moula, 2005). Climate change is projected with decreasing average rainfall by about 6 mm per month during the rainy season. Such changes in temperature and precipitation are likely to limit the development progress in many sectors in Sudan. Around 70% - 80% of the people depend on agriculture, of which 80% – 90% depend on rain-fed agriculture, which is declining and uncertain, making life very difficult for traditional farmers and herders, and affecting their livelihoods severely.

The country has a large range of ecosystems and agricultural systems. Throughout much of the country, water resources are limited, soil fertility is low and drought is common (NAPA, 2007). The most vulnerable people are the farmers in western, central and eastern Sudan, whose livelihoods are exposed to the severity of drought and variability of rainfall (in terms of amount, distribution and frequency). Drought threatens approximately 12 million hectares of rainfed land, particularly in the northern Kordofan and Darfur states. Between 1971 and 2001, over ten million people in Sudan were affected by drought. In 2000, drought caused reduction of food supply and three-fold prices increase compared to the same period in the previous year (Schmidt and Karnieli, 2000).

The paper intends to identify and measure the severity of climate change impacts and to suggest possible adaptation strategies for traditional agriculture in the Kordofan region. It is suggested that there would be a significant decrease in Kordofan's agricultural productivity and a reduction in gum Arabic, the state's primary cash crop.

2. Research objectives

The overall objective of this paper is to study the effects of climate change on traditional rainfed agriculture during the period 1976 - 2005 in Sheikan locality. Specific objectives are:

a. To study the effects of climate change in the study area and its impacts on the traditional rain-fed agricultural activities;
b. To study the coping mechanisms and strategies to mitigate climate change impacts in study area.

3. Research Questions

Traditional rain-fed agriculture represents the main subsistence in Sheikan locality. During the last decades, and due to climate change, the agricultural production drastically decreased. Therefore, this study intends to answer the following questions:

1. What are the effects of climate change in the study area?
2. What is the impact of climate change on agricultural activities in Sheikan locality?
3. What are strategies and mechanisms used to cope with and to adapt agricultural practices on climate change in Sheikan locality?

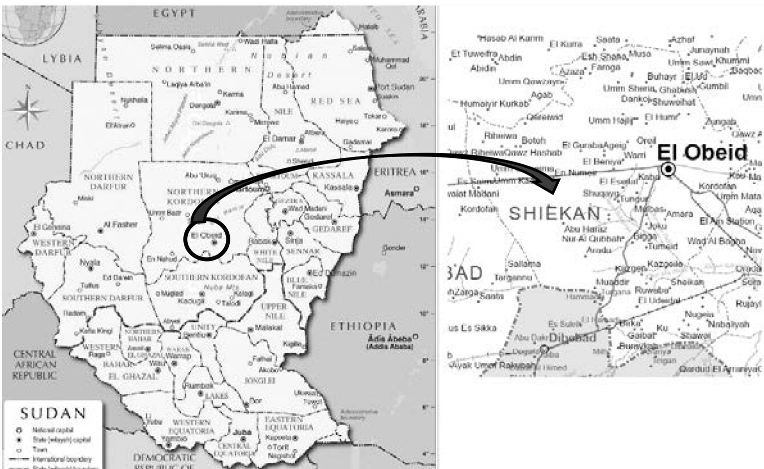
4. Research methodology

4.1 Study area

The study area is located in North Kordofan state, latitude 12° 00' - 16° 35'N and longitude 27° 28' - 32° 20' E, with an area of 190,840 km^2. The state comprises nine localities, of which Skeikan locality is the study area. Sheikan lies between latitude 12° 30' - 13° 37' N and longitudes 29° 33' - 30° 30' E, extending over an area of 8,080 km^2 (Figure 1)

(Elobeid Survey Office, 2007). The study area is located within the so-called semi-arid zone characterized by high temperatures all the year and dramatic variability in rainfall, affecting the agricultural production (Tareeh, 1994).

The climate is semi-arid with a mean annual rainfall ranging from less than 100 mm in the North to about 350 mm in the South, concentrated in the summer months (June to September), with August being the wettest month, and with precipitation varying in both time and space (Hulme, 2001). The mean annual temperature in the area is about 20°C, with peaks as high as 45°C during day time in summer. The vegetation in the study area is sparsely scattered as a result of the low amount of rainfall and extreme drought conditions (Schmidt and Karnieli, 2000). Therefore, *Acacia* species are the most dominant trees adapted to such climate. In the northern part of the area the *Leptadenia pyrotechnica* is very common. The understory consists mostly of grasses such as *Echinochloa colonum, Aristida mutabilis, Dactyloctenium aegyptium, Tribulus longipetalus*, and *Eragrostis tremula*.



Source: www.nationsonline.org

Figure 1: Location of the study area in North Kordofan State

The land use in North Kordofan State concentrates on a mix of rainfed cultivation and pastoral grazing. The most common crops on the sandy soils in the north are millet (*Pennisetum typhoideum*), sesame (*Sesamum indicum*), karkade (*Hibiscus sabdariffa*), groundnuts (*Arachis hypogaea*) and watermelon (*Citrullus vulgaris*). On the clay soils in the South, sorghum (*Sorghum vulgare*) replaces millet. In addition to cultivating crops, people also tap the indigenous *Acacia senegal* trees for gum arabic. (Khogali, 1991).

4.2 Material and methods

The statistical approach depended on the descriptive statistics analysis of quantitative meteorological and climate data collected in the period from 1976 to 2005, in order to determine the degree of correlations between different variables for finding the effects and impacts of climate change.

The historical approach deals with studying such phenomena and formulating the hypothesis that governed the relation of the variables, collecting the necessary information for testing the hypotheses during a period of time. These sequences will help to understand new views regarding the past and its relation with the present and future, and also, to make use of the past, in order to predict the future.

The regional approach is one of the most important approaches in the field of applied studies, which could be useful in future planning. Through this approach the research data was collected from Sheikan locality and verified.

The study depended on two data sources, primary data from structured questionnaires that were distributed randomly to 150 farmers (2% of the total population) in four administrative units in Sheikan locality. As the population of the study area is homogeneous, simple random sampling was adopted (Table 1). Secondary data was gathered from relevant references, books, journals and recent publications. Data was analyzed according to the three approaches, using Statistical Package for Social Sciences (SPSS Version 18).

Table 1: Distribution of samples in the study area

Village	No. of family	No. of sample	%
Khor Tagat	900	45	30.1
Kazgail	700	35	23.3
Abu Haraz	1000	50	33.3
Um Ishara	400	20	13.3
Total	3000	150	100.0

5. Results and discussion

There are different relations between climate factors affecting the agricultural production in the study area. The results of correlations between climate factors indicated a strong positive relation (+0.93) between rainfall and relative humidity; on other hand, a strong negative relation was obvious between rainfall, temperature and evaporation (-0.80, -0.72, respectively). This situation outlines the determinant factors in the farming system in the study area (Table 2), because the crops cultivated in the area have different climate requirements in terms of water and temperature.

Table 2: Correlation between climate variables in Sheikan locality

Variable	Rainfall	Temp.	Rel. Humidity	Evaporation
Rainfall	-	- 0.80	+ 0.98	0.72-
Temp.	-0.80	-	0.93-	+ 0.17
Rel. Humidity	+0.98	-0.93	-	- 0.61
Evaporation	- 0.72	+0.17	0.61-	-

For instance, it was found that the suitable water requirement for millet and sorghum is between 250 – 500 mm with a season length of more than 90 days on average, while the suitable water requirement for groundnut is quite high (450-500 mm) with a short season length (around 60 days) (Table 3).

Table 3: Temperature and water requirements for some agricultural crops

Crop	Temp. (C°)	Max. RF (mm)	Water requirement (mm)	Season length (day)
Millet	24-35	500	250-500	70-120
Sorghum	25-35	250	250-500	70-80
Sesame	25-27	625	200-500	80-120
Groundnut	24-34	900	450 -500	60

The most important climate factors which affect the productivity and production in the study area are rainfall and temperature. The results of the current paper revealed that both productivity and production of watermelon has a strong negative relation with rainfall (-0.55 and -0.51), respectively, that means during the low rainfall season the farmers used to cultivate watermelon as cash crop to compensate the loss and failure of other food crops like millet, sorghum and sesame (Tab 4). This practice is considered to be one example of the indigenous knowledge adopted by the farmers through their long experience with a changing environment.

Table 4: Correlation between some agricultural crops with rainfall and temperature

Crop	Temp.		Rainfall	
	Productivity	Production	Productivity	Production
Millet	-0.05	-0.09	+0.19	+0.55
Sorghum	+0.27	+0.03	+0.38	+.065
Sesame	-0.02	-0.02	-0.32	+.055
Groundnut	+0.23	+0.24	+0.02	+0.02
Watermelon seed	+0.05	+0.08	-0.55	-0.51
Roselle	-0.06	+0.35	+0.36	+0.33

In normal condition, sorghum is one of the important food crops cultivated in the study area, and has a productivity of more than 6 sacs/makhamas*. But in this study, the majority of respondents (66%) reported the reduction of production of sorghum to less than 2 sacs per makhamas (Table 5). This was attributed to volume and distribution of rainfall, which are very important in rain-fed agriculture. As a result of

* 1 makhamas = 1.75 feddan = 0.42 ha

climate change the study area was affected very much in the last decades.

Table 5: Mean production of sorghum in Sheikan (sac/makhamas)

Production (sac/makhamas)	%
> 2	66.7
2 – 3	24
4 – 5	9.3
< 6	0

The main effects of climate change in the study area as mentioned by the interviewed respondents were rainfall fluctuation, low soil fertility and others signs (67%, 28% and 5% respectively) (Figure 2, left). These signs directly affected the activities of the farmers and forced to reduce the farming time of crops. The main reason behind that, as was proved by the respondents, is rainfall fluctuation (53%) (Figure 2, right).

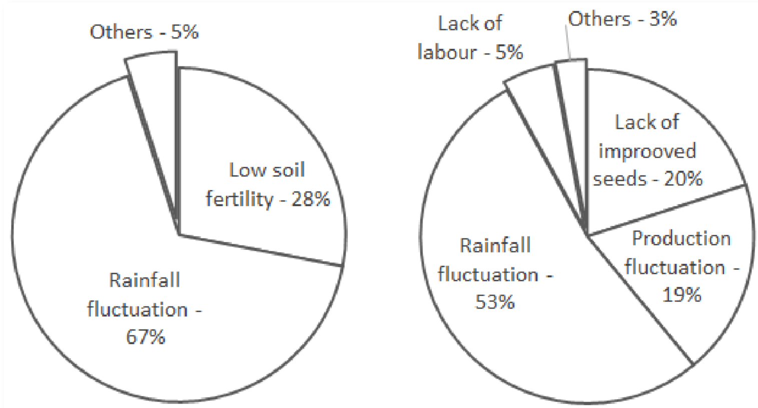


Figure 2: Effects of climate change on agricultural activities (left); Reasons of late farming of crops in Skeikan locality (right)

As consequences of climate variability mainly due to rainfall fluctuation with the loss of productivity and soil fertility, the farmers in the study area developed some indigenous strategies to cope with the impacts of climate change. These strategies of adaptation include dry farming (Ramail) which was mentioned by the majority of the respondents (62%)

(Fig. 3, left). The most motivating factors that made the farmers to rely on specific crops in the study area are to select and cultivate crops that are suitable for the temperature which is very high during the summer time as mentioned by the majority of respondents (65%) (Fig. 3 right).

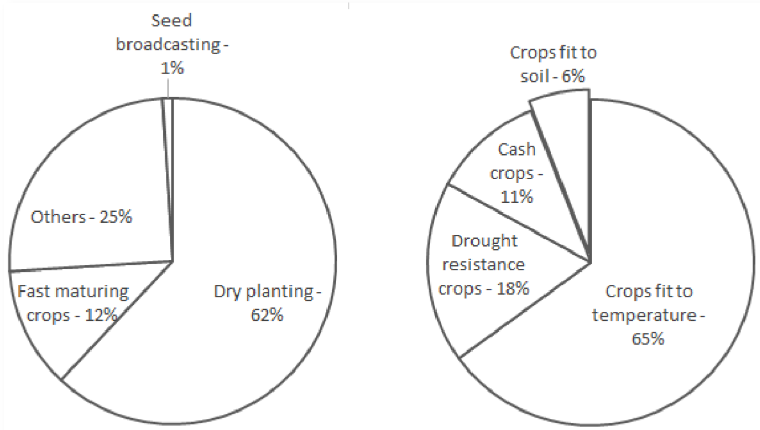


Figure 3: Adapted strategies used for planting crops with low rainfall (left); Factors motivating farmers to plant specific crops in Sheikan (right)

6. Recommendations

Based on the research findings, the following recommendations are to give:

- Adoption and maintenance of agroforestry systems and diversification of cropping to include trees, livestock.
- Improvement of crop management and use of systems based on land use planning.
- Protection and reclamation of soil with application of recommended crop patterns.
- Improvement of agricultural productivity in vertical direction by adoption of intermediate technologies.
- Achieving measures of sustainable management in natural resources and technology improvement

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Can Rain Water Harvesting Mitigate Flooding Associated with Climate Change in Urban Areas? A Case Study of Jinja Municipality, Uganda

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Abstract

The study assessed the potential of rainwater harvesting as a mitigation measure to climate change associated flooding in Jinja Municipality. The methodology involved use of both interviews and observations. There are attempts to collect rainwater in some areas of the city while other areas did not have any mechanisms in place. Specifically, areas with rainwater gutters and harvesting tanks experienced less frequency of floods as compared to areas without gutters and tanks. The flooding was also associated with poor waste management, inadequate drainage systems, and increased surface runoff because of increased infrastructural developments like roofs, roads, pathways and concrete compounds that do not let rain water infiltrate in the soil. In conclusion, rainwater harvesting has a great potential of mitigating flooding associated with climate change in urban areas.

Keywords: climate change, water security, mitigation, rain water harvesting, floods

1. Introduction

Uganda is a landlocked country located in East Africa covering 24.1 million hectares with a current population of 36 million people, according to the Uganda national bureau of statistics 2014, with a heavy dependence on natural resources. Climate change is the change in the weather of an area for a long period.

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Climate change continues to be a major global challenge as it is associated with a number of impacts for example heat waves, droughts, stormy rainfalls, fires, and floods (de Menocal, 2001; Polyak, 2001). These incidences affect the ecological system and human society that sometimes leads to human as well as animal migration (Calvin, 2002). One of the consequences of climate change is increased variability in rainfall amounts and distribution that result in floods. (Polyak, 2001). In some places of Uganda the frequency and intensity of the rainfall has greatly increased and resulting in floods. For example, in Jinja, Soroti district, floods in 2007 have affected food crops, especially root tubers like cassava. Floods have negative impact on secured water supply. Especially the fact that floods are followed from drought periods lead to water scarcity (Zhang, 2003). The scarcity is worsened by the increasing water use due to population growth (Erlandson, 2009). This therefore calls for mitigation measures to prevent flooding.

Jinja Municipality is the second largest town in Uganda, located north of Lake Victoria and south of Lake Kyoga. The town frequently receives heavy rains associated with climate change, and continues to grapple with flooding problems whenever the heavy rains occur (Hassan, 2009). However, when the dry season sets in water becomes scarce although Jinja is endowed with natural water sources like Lake Victoria and river Nile, the greatest river in Africa. Water is supplied to the consumers by the National Water and Sewerage Corporation, under use of hydroelectric power. However, power shortages affect also water supply to the people in the town. So when it rains floods do occur and lead to economic loss that amounts to millions of shillings to the vendors. Therefore, it is necessary to develop mitigation measures to the flooding problem.

Floods have effects like transmission of waterborne diseases, soil erosion, destruction of crops and plants (Salas, 2009). Rainwater harvesting is important as it is a kind of energy saving strategy, and supports livelihoods: where there is water on earth, virtually no matter what the physical conditions; there is life (Rothschild and Mancinelli 2001).

One of the hypothesized climate change mitigation measures suggested by the intergovernmental panel on climate change was rainwater harvesting (IPCC, 2007). Rainwater harvesting is the collection and concentration of runoff from roofs or ground surfaces. This study was carried out to assess the potential of rainwater harvesting as a mitigation measure to flooding in Jinja municipality.

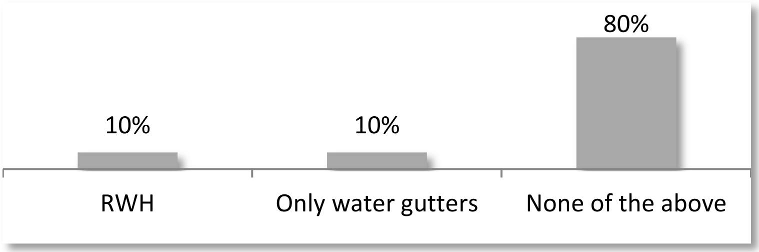
2. Materials and methods

The study methodology involved use of both interviews and observations. 50 buildings were observed and their owners or persons in charge of the building were interviewed about rainwater harvesting on the building. For the assessment, five buildings were randomly selected in ten roads in the town.

3. Results

It is observed that there are attempts to collect rainwater in some areas of the city while other areas did not have any mechanisms in place (Fig. 1). Areas with rainwater gutters and harvesting tanks experienced less frequency of floods and water borne diseases as compared to areas without gutters and tanks. These floods were also associated with poor waste management, inadequate drainage systems that are poorly distributed on buildings and roads where they even get blocked with rubbish accelerating floods in the municipality thus floods. Increased infrastructural development such as roofs, roads, pathways and concrete compounds prevent rainwater infiltration in the soil, and the run off water increase flooding.

In conclusion, rainwater harvesting has a great potential of mitigating flooding in urban areas. It also increases water security and reducing pressure on open water bodies since the harvested water can be used. Though it is not ready for drinking purposes, it can be used for flushing toilets, feeding animals or irrigation, especially water collected along the roads or from compounds. Water collected from the roof can be used for washing clothes and dishes, house cleaning and animal feeding.



80% of the buildings does not have even water gutters. 10% of the buildings has water gutters but without tanks. 10% of the buildings has both water gutter and water tanks

Figure 1. Rain water harvesting on buildings in Jinja town

Urban planning should consider rainwater harvesting, using environmental criteria in addition to economic, social and technological factors. Since the coverage of rainwater harvesting is low, there is a need of comprehensive knowledge on climate change adaptation and more sensitization about its values, including increasing water security towards sustainability (Erlandson, 2009). It should be noted that some of the decisive factors, such as the cost, the available space, and the tank sizes available on the market, should be considered (Mwenge Kahinda, 2007).

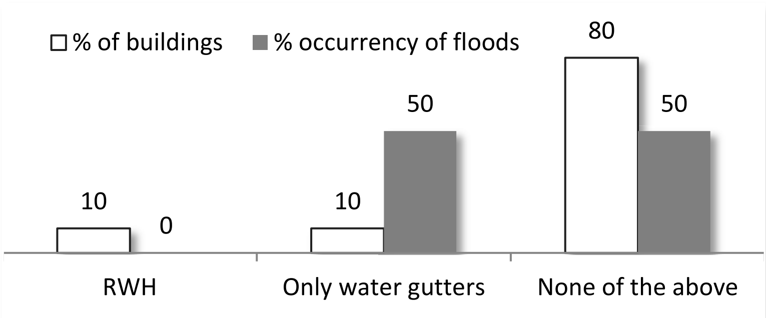


Figure 2. Effect of rainwater harvesting on floods in Jinja

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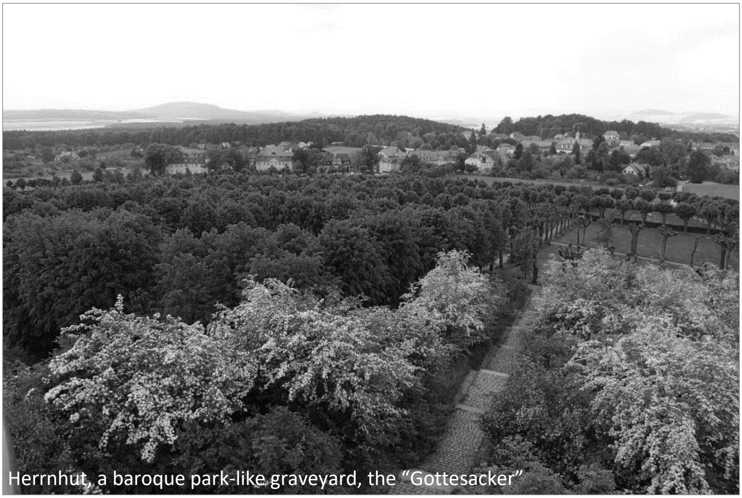
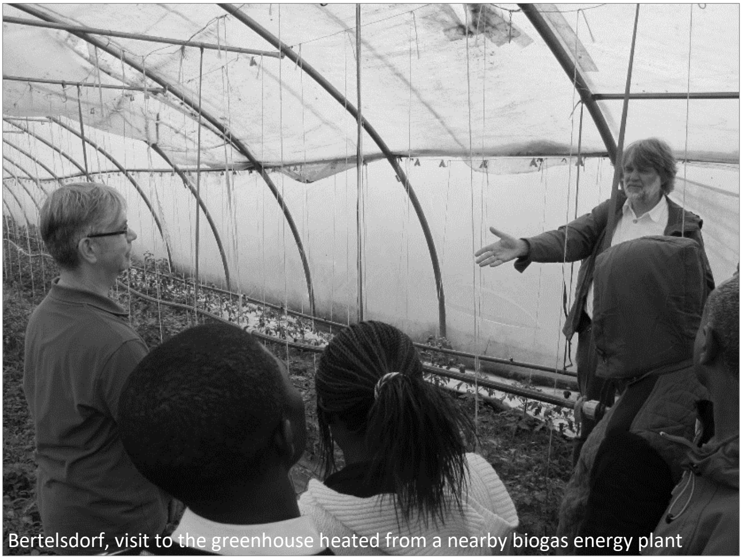

Herrnhut, a baroque park-like graveyard, the “Gottesacker”


Bertelsdorf, visit to the greenhouse heated from a nearby biogas energy plant

Agroforestry, Reforestation, and Climate Change

Agroforestry in Reducing Emissions from Deforestation and Forest Degradation (REDD+): Africa, Where Are You?

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Abstract

This paper highlights the position of agroforestry in post-Kyoto arrangements, particularly the mechanism for Reducing Emissions from Deforestation and Forest Degradation (REDD+). It summarizes the prospects to mitigate global climate change and adaptation, especially in Africa, where the majority of agroforestry systems occur. Since long agroforestry is known as a management approach to sustain farms and landscapes, enhance livelihoods of smallholder farmers, and to promote biodiversity conservation, particularly in the tropics. This is possible by constant supply of multiple important goods and services, and by increasing land productivity and rural incomes. However, the importance of agroforestry has received recently high attention from both industrialized and developing countries. It provides sustainable and low-cost opportunities to mitigate climate change by reducing greenhouse gases (GHGs) concentrations in the atmosphere, and as natural adaptation measure to climate change effects. Current global prediction models show that area under agroforestry management will increase substantially. Thus, it reveals even more opportunity to capture and store CO_2 (C sequestration) and to enhance GHGs sinks. In conclusion, this paper highlighs efforts to incorporate agroforestry into national REDD+ strategies in Africa.

Keywords: agroforestry, greenhouse gases, carbon sequestration, REDD+, co-benefits

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1. Introduction

Agroforestry, the intentional growing of trees together with crops, pasture and/or animals, is key for conserving natural resources and generating income (ICRAF, 2000). It is known as a land management approach to sustain farms and landscapes, enhance livelihoods of smallholder farmers and to promote biodiversity conservation particularly in the tropics by constant supply of multiple important goods and services, and by increasing rural incomes and land productivity. The International Panel on Climate Change (IPCC) Third Assessment Report on Climate Change has recognized the potential of agroforestry for addressing multiple problems and delivering a range of economic, environmental and socioeconomic benefits (McCarthy et al., 2001).

In light of the high potential of agroforestry for food security, climate change adaptation and mitigation, tree-based agricultural systems are currently being promoted in many parts of Africa (Garrity et al., 2010). Indeed, tree based agriculture systems have successfully been established in many regions of the world (Sendzimir et al., 2011). Many of the agroforestry trees that are introduced are long-lived species that are expected to grow on farmers' fields for several decades. Incorporation of agroforestry trees into crop fields facilitates long term planning to enhance food security and national income. These long planning horizons make consideration of particularly trees of importance. Hence, agro-ecosystems can be designed to assist adaptation of communities and households to local and global changes including those related to climate change (Van Ardenne et al., 2003).

Evidence of the multiple costs and multiple benefits from agroforestry is growing worldwide (Hoang et al., 2013). In practice, at sub-national level, agroforestry has been deployed in the last 20 years as a strategy for addressing deforestation with integrated conservation and development projects (Mukadasi et al., 2007), and in emerging REDD+ sub-national projects (Minang and van Noordwijk, 2013). Current global prediction models show that area under agroforestry management will increase substantially and thus considerable increase in opportunity to capture and store atmospheric CO_2. This indicates even more potential for agroforestry to enhance GHGs sinks in the new era of post Kyoto arrangement. Estimates of the carbon sequestration potential of agroforestry systems range from 0.7-1.6 Gt (Trexler and Haugen, 1994) to 6.3 Gt (Brown et al., 1996).

At the UNFCCC-COP 13 meeting in Bali, a roadmap for the implementation of Reducing Emission from Deforestation and Degradation (REDD) was officially recognized, the concept of REDD was being developed globally. In 2010, at COP-16 as set out in the Cancun Agreements, REDD became REDD-plus (REDD+), to reflect the new components. REDD+ now includes: reduction emissions from deforestation, reduction emissions from forest degradation, conservation of forest carbon stocks, sustainable management of forests and enhancement of forest carbon stocks (UNFCCC, 2011). It has generated excitement about possibilities for getting underway on climate change mitigation quickly and cheaply. It has also been broad enough to serve as a canopy under which a wide range of actors can grow their own trees. No idea for saving the world's tropical forests has generated about the same excitement and commitment as REDD+ has done. Now, international funding for REDD+ primarily comes from development aid budgets and has contributed to a broadening of the scope of REDD+ (Angelsen et al., 2012).

However, whether agroforestry becomes a core element of REDD+ depends on a country's forest definition. Where carbon stocks in agroforestry cannot be directly targeted as "forest" in REDD+, agroforestry can be included in REDD+ strategies, as ways to (1) land sparing and (2) provide alternative sources of products derived from forest over-exploitation or conversion, to avoid leakage from forest protection efforts (Minang and van Noordwijk, 2013). Therefore, this paper highlights potentials of agroforestry to contribute to REDD+ and assesses how agroforestry is mainstreamed in national REDD+ strategies, with a focus on Africa.

2. Methods

Data were collected by reviewing recent empirical literature, the author's own experience and grey literature. The review intended to summarize agroforestry potentials and its prospects to mitigate global climate change and adaptation especially in Africa where significant agroforestry systems occur (Minang et al., 2014).

3. Discussion

3.1 Potentials of agroforestry

The many different agroforestry systems deliver a variety of direct and indirect benefits for humans. The interest of investigating agroforestry under a changing climate comes from the increased recognition of the great potentials of agroforestry practices. It promotes sustainable productions that enhances agro-ecosystem diversity and resilience, reverses environmental degradation, reduce deforestation and enhances fuel wood supply. Tree-based farming systems store carbon in soils and woody biomass, and they may reduce greenhouse gas emissions from soils (Smith and Olesen, 2010). These notable contributions of agroforestry are explained more in the below thematic areas.

3.1.1 Agroforestry for biodiversity conservation

Ecosystems and species are important in sustaining human life while the physical condition of our planet earth is declining at an alarming rate. So, the need for immediate action to conserve biodiversity is receiving considerable attention worldwide. Scientists and policy makers are becoming increasingly aware of the role agroforestry plays in conserving biological diversity in both tropical and temperate regions of the world (Jose, 2009). The mechanisms by which agroforestry systems contribute to biodiversity have been examined by various authors (e.g. Schroth et al., 2004; McNeely, 2004; Harvey et al., 2006). Agroforestry plays crucial roles in conserving biodiversity like habitat provision for species, preservation of germplasm of sensitive species, and it provides connectivity by creating corridors between habitats. Moreover, agroforestry providing other ecosystem services such as erosion control and water recharge, thereby preventing the degradation and loss of surrounding habitats.

3.1.2 Agroforestry for carbon sequestration

Carbon sequestration involves the removal and storage of carbon from atmospheric CO_2 in carbon sinks (such as oceans, vegetation, or soils) through physical or biological processes. The incorporation of trees or shrubs in agroforestry systems can increase the amount of carbon sequestered compared to a monoculture field of crop plants or pasture (Kirby and Potvin, 2007). The largest amount and most permanent form of carbon may be sequestered by increasing the rotation age of trees and shrubs and/or by manufacturing durable products from them upon harvesting. Nair et al. (2010) showed that carbon sequestration potential of the vegetation component (above and below ground) ranged from 0.29 Mg ha^{-1} yr^{-1} in a fodder bank agroforestry system of West African Sahel to 15.21 Mg ha^{-1} yr^{-1} in mixed species stands of Puerto Rico. Thus, agroforestry sequesters a significant amount of carbon (C) and could be highly considered in REDD+.

Additionally, 630 million ha of unproductive crop fields and grasslands could be converted to agroforestry, representing a carbon sequestration potential of 391,000 Mg C yr^{-1} by 2010 and 586,000 Mg C yr^{-1} by 2040 (Jose, 2009). The extent of carbon sequestration, especially in soils, in agroforestry systems of West African Sahel was investigated by Takimoto et al. (2008) by comparing two traditional parkland systems, two improved agroforestry systems (live fence and fodder bank), and abandoned land. The authors concluded that improved agroforestry practices such as live fence and fodder bank sequestered more C than traditional and abandoned lands. All of these case studies further add to the growing body of literature that indicates agroforestry systems have the potential to sequester greater amounts of above and belowground carbon compared to conventional farming practices.

3.1.3 Agroforestry and ecosystem stability

Tree canopies can create a more adequate microclimate for crops and a more resilient ecosystem for better food production (Unruh et al., 1993). Microclimatic improvement through agroforestry has a major impact on crop performance as trees can buffer climatic extremes that affect crop growth (Mbow et al., 2013). In particular, the shading effects of agroforestry trees in African tropical countries can buffer temperature and atmospheric saturation deficit reducing exposure to supra-optimal temperatures, under which physiological and developmental processes and yield become increasingly vulnerable (Lott et al., 2003). Agroforestry contributes to ecosystem functions in water recycling by increased rainfall utilization compared to annual cropping systems. Lott et al. (2003) reported that about 25% of the water transpired by trees is used during the dry season, indicating that they are able to utilize off-season rainfall (comprising 15–20% of the total annual rainfall) and residual soil water after the cropping period, with the rest being lost by evaporation (40%) or deep drainage (33–40%). This complementarity between trees and annual crops extends possibilities of soil moisture uptake, hence making soil resource utilization more efficient than in pure monoculture systems (Jackson et al., 2000).

3.1.4 Agroforestry as a strategy for avoided degradation

Together with conversion into agricultural land, wood fuel, charcoal and timber production have been documented as frontline drivers of forest degradation in several African countries and a driver of deforestation of dry forests there (Minang et al., 2014). Therefore, on-farm timber and wood fuel supplies are likely to relieve forests of anthropogenic pressures from an increasing demand for timber and wood fuel. On-farm timber is increasingly becoming mainstream timber sources in a number of tropical countries across the world (Robiglio et al., 2011). Kimaro et al., (2011) clearly demonstrate a significant contribution of rotational agroforestry systems to reduce forest degradation and offset CO_2 emissions through on-farm wood supply in semi-arid Morogoro, Eastern Tanzania.

3.1.5 Agroforestry as a strategy for avoided deforestation

The land sparing or intensification hypothesis suggests that investments made in agriculture result in increased productivity per unit area through increased inputs and better technology (Minang et al., 2014). Once these interventions enable adequate supply of food, fuel and fiber, less forest land would be cleared for agriculture and carbon storage (Borlaug, 2009). However, evidence of how far agroforestry intensification and diversification has avoided deforestation has largely been anecdotal cases studies (Minang et al., 2014). Research on the context, demand dynamics for agroforestry products, wood, and other tree products is therefore needed in many places in Africa and along tropical forest margins.

3.1.6 Agroforestry in soil fertility improvement and crop performance

It is well known that intensive use of soils together with high population pressure, leads to depletion of soil nutrient reserve as well as accelerated degradation of water resources. This has resulted into lower production and yields in agriculture. Agroforestry can reverse this situation. It cycles plant nutrients, for enhancing the nutrient and water retention capacity of the soil, increase soil biotic and faunal activities and reduce the acidity of acidic soils by adding organic matter applied as mulch, tree pruning's, leaf litter, compost or animal manure. Agroforestry is considered to be more sustainable and protect the soil better than annual mono-crop production systems (Kang and Akinnifesib, 2000).

3.1.7 Protective role of agroforestry

Increasing population pressure in highly populated areas in African countries frequently has resulted in the cultivation of hill slopes and marginal lands, which aggravates soil erosion and land degradation. On hills or sloping lands soil erosion is a major problem, affected by the length of the slope and the gradient of the land (Kang and Akinnifesib, 2000). Agroforestry systems such as alley cropping protect more effective against soil erosion than monoculture systems due to the combined effects of soil fixation and run-off water infiltration by the extended root system from woody species and crops, the year round surface cover by annual and perennial plants, mulch cover from plant residues and hedgerow prunings, and the barrier effect of hedgerows (Craswell et al., 1997, extended).

3.1.8 Contribution of agroforestry to food security

Establishment of agroforestry on land with low tree cover has been identified as one of the most promising strategies to raise food production without additional deforestation (Bayal et al., 2011). Food production is typically more important to farmers than indirect services of agroforestry like enhanced soil fertility or avoided deforestation (Bucagu et al., 2013). With growing pressures from climate change and demographic development, farmers have to produce significantly more food on less land. A recent paper showed that agroforestry reduced food insecurity during drought and flooding in western Kenya by 25%, due to availability of annual and perennial crop products (Thorlakson and Neufeldt, 2012). In most cases, assets related to ecosystem services and to food security are the main motivating factors in agroforestry adoption (DeSouza et al., 2012; Skole et al., 2013). Agroforestry is therefore often considered as a way to sustainably intensify farming practices for enhanced food security using socially and cost-effective management techniques.

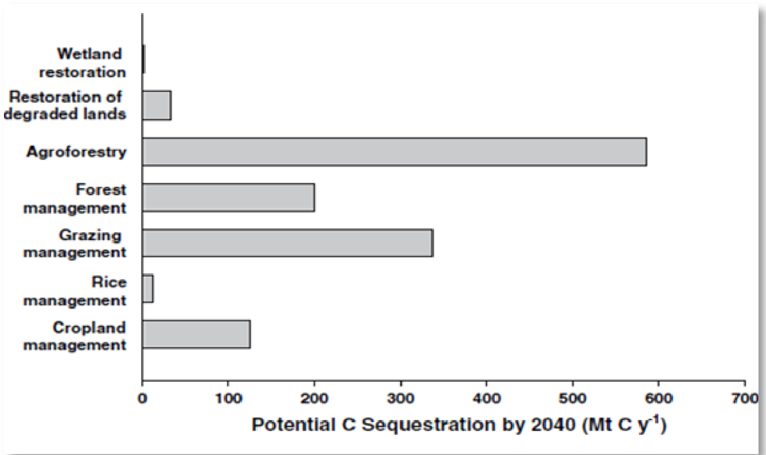
3. 2 Agroforestry as part of REDD+ by forest definition

Many agroforestry systems can be part of REDD+, according to the current definition of “forests” within the United Nations Framework Convention for Climate Change (UNFCCC). The UNFCCC as part of the Kyoto Protocol defines forest as “a minimum area of land of 0.05-1.0 hectare with tree crown cover (or equivalent stocking level) of 10-30 % with trees having the potential to reach a minimum height of 2-5 meters at maturity in situ” (UNFCCC, 2002). Therefore, agroforestry systems may meet the forest canopy cover threshold chosen by the country (10–30%) and thus become part of REDD+. FAO defines forest as “Land spanning more than 0.5 hectares with trees higher than 5 meters and a canopy cover of more than 10 percent, or trees able to reach these thresholds in situ, which is not primarily under agricultural or urban land use” (FAO, 2000). As the explicit disqualifier of agriculture of the FAO, forest definition was not followed by the UNFCCC (van Noordwijk and Minang, 2009). For instance, Bisseleau et al., (2009) showed that at least some cocoa agroforestry systems in South Cameroon have a canopy cover of 88%, clearly above the threshold set by UNFCCC. This implies for UNFCCC forest definition that all cocoa agroforestry systems in Cameroon have the potential to be forest, and should be included in REDD+.

3. 3 Agroforestry in climate change mitigation and adaptation context

Lack of investment reduces further access of African farmers to fertilizers, irrigation and energy-intensive mechanized production approaches, while conservation policy (regulations) restrict their ability to expand cropping areas (Beddington et al., 2012). Climate change is making it even harder for farmers to survive with these problems. Agroforestry is often considered a cost-effective and sustainable strategy for climate change mitigation and adaptation.

Regarding adaptation of agricultural production practices to climate change, agroforestry has potential to moderate climate extremes, in particular high temperatures, as well as intra-annual climatic fluctuations. Agroforestry has a particular role in the mitigation of atmospheric accumulation of greenhouse gases (IPCC, 2000). Of all land-use types considered in the IPCC ''Land-Use, Land-Use Change and Forestry Report'', agroforestry practices were evaluated to have the highest potential for carbon sequestration in non-Annex I countries or developing countries (Fig. 1). More, agroforestry systems offer opportunities for the creation of synergies between adaptation and mitigation, and have a technical mitigation potential of 1.1 - 2.2 PgC* in terrestrial ecosystems over the next 50 years (Solomon et al., 2007).



Source: IPCC (2000)

Figure 1: Management regimes potential for Carbon Sequestration by 2040

* Petagrams of carbon

The importance of agroforestry has received wide attention in recent times from both industrialized and developing countries. This is due to the recognition that agroforestry systems compared with technological investments provide high, sustainable, low cost opportunities to mitigate climate change by reducing greenhouse gases (GHGs) concentrations in the atmosphere, and that it could also help natural and human systems adapt to climate change effects (Minang and van Noordwijk, 2013).

3.4 African countries with Agroforestry in REDD+ strategies

Although many African countries practice agroforestry, full potential of agroforestry in emerging opportunities like REDD+ has not been well taped. This could partly be because of agroforestry is not being mainstreamed within national policies, including those related to REED+. Considerations for agroforestry within REDD+ remain embryonic at national and sub-national level in African countries (Minang et al., 2014). In Africa only 11 out of 56 countries, in other terms 20 %, have included agroforestry in their national REDD+ strategies and REDD Readiness Preparation Plans (RPP). These countries are Burkina Faso, Cameroon, Central African Republic, Republic of Congo, Democratic Republic of Congo, Ethiopia, Ghana, Kenya, Liberia, Tanzania and Uganda (Minang et al., 2014). Though agroforestry features a prominent dimension of sustainable agriculture intensification in Africa, complementary policy actions and research might be needed to enable the achievement of its full potential at national and sub-national levels (Rudel et al., 2009).

3. 5 Challenges to agroforestry in Africa

There are still technical, political and economic challenges remaining, those to overcome would further enhance the potential contribution of agroforestry to REDD+ in Africa. Technical challenges include, lacking access to good quality planting material for desired species, limited agronomical understanding of optimal shade management in sustainable intensive and diversified agroforestry systems, and processing of products for value addition (Pretty et al., 2011). Economic and policy challenges include land tenure, trees and carbon, poor market infrastructure, long waiting periods for recovery of investments and labor shortages (Santos-Martn et al., 2012). Usually competing claims in land use rights, land tenure, and often insecure land tenure prevents farmers from investing in sustainable land use practice like agroforestry.

4. Conclusions and recommendations

Agroforestry should not be ignored by African REDD+ designers since it enhances carbon sequestration, promotes biodiversity conservation, ecosystem stability, improvement of soil fertility and crop performance. It is also potential as a strategy for avoided land degradation and deforestation, and for contribution to food security. Still most of the African countries do not specify how agroforestry practices are integrated in REDD+ strategies, and are yet to deploy agroforestry in the context of REDD+. To enhance agroforestry contributions to REDD+ at landscape level it is crucial to understand the demand and employ better planning approaches in which land is shared between agroforestry, protected forests and other land uses with clear and agreed rules for management (van Noordwijk and Minang, 2009). Research on the context, demand dynamics for agroforestry products, especially wood and other tree products, is therefore needed in many places in Africa. More quantitative evidence, and understanding of institutional and policy arrangements which enable agroforestry contribution to REDD+ are needed. Further research that helps to quantify the REDD+ and multiple benefits of agroforestry beyond the micro scale help to reinforce policy actions that are supportive for agroforestry in REDD+ and climate change in general at both national and global levels.

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Carbon Sequestration and Greenhouse Gas Emissions in Agroforestry: Summary of Global Data and Implications for Africa

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Abstract

It has been recognized that agroforestry provides various benefits and services including increasing and diversifying crop production, preventing soil erosion, enhancing soil fertility and water quality, and conserving biodiversity. In addition to these various benefits and services, carbon (C) sequestration under agroforestry has received particular attention. However, there is a lack of comprehensive understanding of C sequestration and changes in greenhouse gas (GHG) emissions under agroforestry. We, therefore, compiled and analyzed 109 data sets for biomass and soil C sequestration rates and 27 data sets for GHG methane (CH_4), and nitrous oxide (N_2O) emissions under agroforestry. Overall, agroforestry (at an average age of 14 y) sequestered 7.8 ± 0.6 t C ha^{-1} y^{-1}, with biomass and soil C sequestration contributing 70% and 30% of that increment, respectively. Soils under agroforestry also oxidized 1.6 ± 0.5 kg CH_4 ha^{-1} y^{-1} and emitted 7.7 ± 1.7 kg N_2O ha^{-1} y^{-1}. Overall, agroforestry was estimated to contribute to mitigating 24.2 ± 11.3 t CO_2 equivalent (eq) ha^{-1} y^{-1} at least at the early stage (around 10 y). The results suggest that agroforestry can offer great potential for C sequestration and mitigate GHG emissions while it provides various benefits and services including restoring degraded lands and securing food for local communities.

Keywords: agroforestry, carbon sequestration, soil, biomass, greenhouse gas flux

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1. Introduction

Increasing GHG emissions that lead to global climate change threaten ecosystems and people's livelihoods (IPCC, 2013). The atmospheric concentrations of the GHGs carbon dioxide (CO_2), CH_4, and N_2O have increased since 1750, and by 2011, the concentrations of these GHGs exceeded their pre-industrial levels by about 40%, 150%, and 20%, respectively (IPCC, 2013). The world is therefore looking for ways to halt the further increase in GHGs. Agroforestry is one of those options (IPCC, 2007; UNEP, 2013). It is defined as any practice to purposefully grow trees together with crops, and/or animals for a variety of benefits and services (Nair et al., 2010; Jose et al., 2012).

Agroforestry can provide various benefits and services (Nair et al., 2010; Jose et al., 2012). In addition, C sequestration has received particular attention as means to slow the increase in atmospheric CO_2 concentrations (Thangata et al., 2012; Luedeling et al., 2014). Agroforestry can increase biomass C stocks as trees consist of 46–51% C (Aalde et al., 2006). It can also enhance soil C sequestration by organic matter turnover processes in soils, such as through enhanced fine root production, rhizo-deposition and litter fall (Beedy et al., 2010; Lorenz and Lal, 2014). The IPCC estimated that the total net annual rate of C stock changes after conversion of agricultural land to agroforestry as 0.50 t C ha^{-1} y^{-1} for Annex I countries (mostly industrialized countries) and 0.22 t C ha^{-1} y^{-1} for non-Annex I countries (mostly developing countries)(Watson et al., 2000).

However, there is a lack of comprehensive understanding of the soil emissions of the GHGs CH_4 and N_2O in agroforestry systems. Some researches reports that N_2O emissions from legume-based agroforestry were greater than from non N-fixing trees or non N-fixing cropping systems (Baggs et al., 2006; Dick et al., 2006). Reduced soil disturbance might possibly lead to high CH_4 uptake in agroforestry compared to adjacent agricultural fields. These results and interactions suggest that, in principle, agroforestry could possibly either intensify or mitigate soil GHG emissions to a small extent, and it is important to gain a comprehensive understanding of total soil GHG emissions in agroforestry systems.

Overall, in spite of the recognized potential of C sequestration in agroforestry, there are few comprehensive and quantitative summary reports of net C sequestration rates, and net changes in overall GHG emissions under various types of agroforestry. Our objectives were to: 1) summarize average C sequestration rates and net GHG emissions across available studies; 2) discuss implications for Africa.

2. Methodology

This study includes the following agroforestry practices: home gardens, improved fallow, intercropping, live fences, parklands, riparian buffer, rotational woodlots, shaded perennial-crop systems, shelterbelts, silvopasture, shifting cultivation, tree plantations on arable land. Here, we compiled data from field-measurements collected worldwide. We selected data that 1) reported C sequestration rates in above and belowground biomass and soils under agroforestry; and 2) compared soil properties (e.g. bulk density, soil organic carbon and nitrogen and pH) and soil CH_4 and N_2O emissions in agroforestry and adjacent agricultural fields.

Total mitigation of net GHG emission in agroforestry, T (CO_2 equivalents ha^{-1} y^{-1}), was quantified as:

$$T = Cb + Cs - M - N \qquad (1),$$

where Cb and Cs are the C sequestration rates in plant biomass and the soil, respectively, and M and N are CH_4 and N_2O emissions, respectively.

Cb and Cs are calculated in units of CO_2 as:

$$Cb = (44/12) \times B \qquad (2a),$$

$$Cs = (44/12) \times S \qquad (2b),$$

from recorded C sequestration rates in biomass (B) or the soil C (S). The constants 44 and 12 are the molecular weights of CO_2 and C, respectively.

M and N are calculated in units of CO_2 eq as:

$$M = 34 \times Ma \qquad (3a),$$

$$N = 298 \times (44/28) \times Na \qquad (3b),$$

where Ma and Na are CH_4 and N_2O emissions rates, respectively, and 34 and 298 are the global warming potentials of CH_4 and N_2O (IPCC, 2013). The additional constants (44/28) convert from activity data that are usually reported per unit of nitrogen to the molecular weight of N_2O

3. Results and discussion

In type 1 agroforestry (tree-crop co-existence type; shaded perennial-crop systems, intercropping, home gardens, live fences, park lands, shelterbelts, silvopasture, and riparian buffers), biomass (0.5 to 11.0 t C ha^{-1} y^{-1}) and soil (0.3 to 7.4 t C ha^{-1} y^{-1}) C sequestration rates varied widely. The divergent sequestration rates may be attributed to different types, density and management of growing trees, soil properties, land-use history, and climate conditions. On average, type 1 agroforestry was reported to sequester 7.2 ± 2.8 t C ha^{-1} y^{-1} consisting of biomass C sequestration rate of 5.0 ± 1.6 t C ha^{-1} y^{-1} (70%) and soil C sequestration rate of 2.2 ± 1.2 t C ha^{-1} y^{-1} (30%).

In type 2 (tree-crop rotation type; improved fallow, rotational woodlots, tree plantations on arable land, and shifting cultivation), rotational woodlots had relatively larger above ground biomass C sequestration rate (5.4 t C ha^{-1} y^{-1}) compared to other agroforestry (3.2 – 5.0 t C ha^{-1} y^{-1}). Tree plantations on arable land had the lowest soil C sequestration rate (0.3 ± 0.1 t C ha^{-1} y^{-1}) among various agroforestry practices (1.0 – 7.4 t C ha^{-1} y^{-1}). On average, type 2 agroforestry (at an average age of 11.8 years) sequestered 2.2 ± 1.1 t C ha^{-1} y^{-1} and 6.2 ± 1.8 t C ha^{-1} y^{-1} through soil and biomass, respectively.

Overall, agroforestry combining type 1 and 2 (at an average age of 14 years) sequestered 7.8 ± 0.6 t C ha^{-1} y^{-1}, with biomass and soil C sequestration contributing 70% and 30% of that increment, respectively. (Fig. 1)

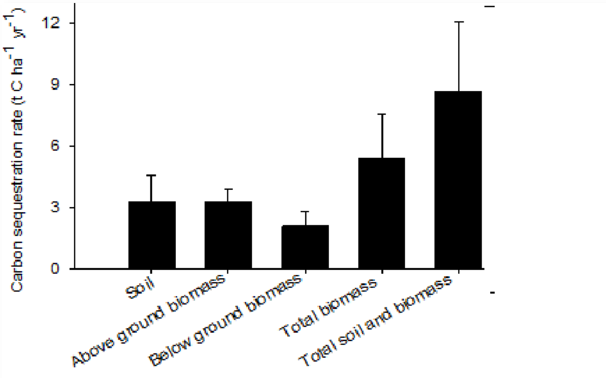

Figure 1: Carbon sequestration rate in the soil, above and below-ground biomass, and total biomass (sum of above and below ground biomass), and total soil and biomass in agroforestry. Error bars indicate standard errors

Our compiled data show that soils under agroforestry had a net CH_4 emission (i.e. uptake) of -1.6 ± 0.5 kg CH_4 ha^{-1} y^{-1}, and net N_2O emission of 7.7 ± 1.7 kg N_2O ha^{-1} y^{-1} (Table 1). Improved follow had the largest CH_4 uptake (-3.2 ± 0.5 kg CH_4 ha^{-1} y^{-1}) and improved follow, shaded perennial-crop systems, and riparian buffer had the largest N_2O emissions (9.1 – 10.1 kg N_2O ha^{-1} y^{-1}), while shifting cultivation and tree plantations had quite low emissions of little over 1 kg N_2O ha^{-1} y^{-1} (Table 1).

Table 1: Observed net methane (CH_4) and nitrous oxide (N_2O) emissions under agroforestry

Agroforestry type	kg CH_4 ha^{-1} y^{-1}	kg N_2O ha^{-1} y^{-1}
Improved fallow	-3.2 ± 1.0	10.1 ± 5.9
Intercropping	*	3.2 ± 0.4
Shaded perennial-crop systems	-1.3 ± 1.0	9.7 ± 7.8
Shifting cultivation	-2.6	1.26
Tree plantations on arable land	-0.14	1.40
Riparian buffer	-0.28	9.11
Total	-1.6 ± 1.0	7.7 ± 3.3

Negative values mean that CH_4 is oxidized in these soils. Shown are means ± 95% confidence interval. *No data available

Combining C sequestration in biomass and soil and mitigation of CH_4 and N_2O emissions, it was estimated that agroforestry can contribute to mitigating 24.2 ± 11.3 t CO_2 eq ha^{-1} y^{-1} at least over the early stage (i.e., up to 25 years) (Fig. 2). Watson et al. (2000) estimated that 630 million ha of unproductive agricultural lands could potentially be converted to agroforestry worldwide and could potentially contribute to mitigate 15 ± 7 × 10^9 t CO_2 eq y^{-1}.

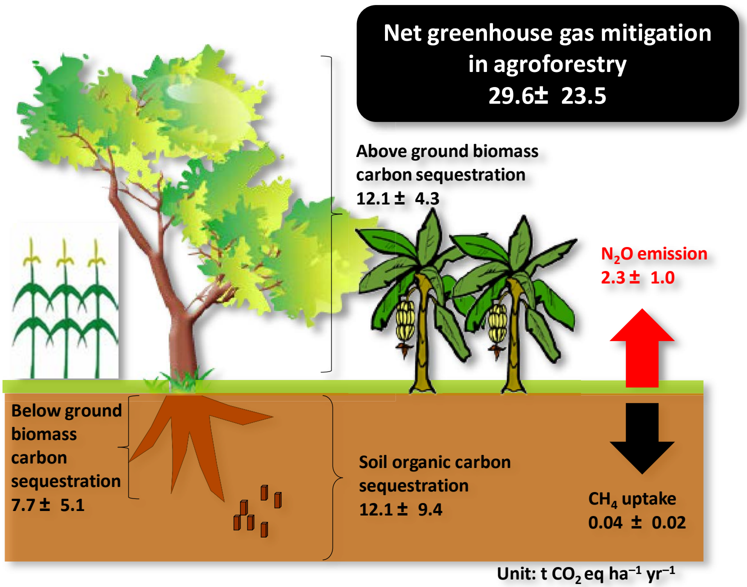

Figure 2: Carbon sequestration rate in plant biomass and the soil, methane (CH_4) and nitrous oxide (N_2O) emissions in agroforestry (mean ± 95% confidence interval) (unit: t CO_2 eq ha^{-1} yr^{-1}

Although there remains large uncertainty in these estimates due to the paucity of available data, the results nonetheless suggest that agroforestry can make a strong and useful contribution to mitigate GHG emissions while continuing to contribute towards food production and restoring degraded lands. Especially, the results provide strong implications for African countries with critical problems of food security and deforestation and land degradation. First, existing indigenous agroforestry practices need to be assessed in regard to their potential for carbon sequestration and it should be identified whether they can be a sink of GHG. Second, it may be considerable to rehabilitate degraded or unproductive land by the means of agroforestry. The conversion may bring multiple benefits including restoring deforested and degraded areas, increasing crop productivity and greenhouse gas mitigation at the same time. Third, currently indigenous agroforestry practices are converted to mono cropping for fast cash acquisition from marketing commercial crops. However, these conversions may cause high loss of soil carbon and soil fertility and contribute to serious problems globally and regionally.

4. Conclusion

Agroforestry systems of the considered cases (at an average age of 14 years) sequestered 7.8 t C ha^{-1} y^{-1}, whereby biomass C sequestration contributed to 70% and soil C sequestration contributed to 30% for it. Soils under agroforestry had a net emission of –1.6 kg CH_4 ha^{-1} y^{-1} and 7.7 kg N_2O ha^{-1} y^{-1}. Overall, agroforestry contributes to mitigating 24.2 ± 11.3 t CO_2 eq ha^{-1} y^{-1} at the early stage (i.e., in the first 10 years). In conclusion, agroforestry offers a great potential for C sequestration and mitigate GHG emissions while it provides various additional benefits and services, including rehabilitating degraded lands and securing food for local communities. It provides strong implications for countries in African continent.

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Propagation Techniques for Ethiopian Highland Bamboo *Yushania alpina* in Amhara Region, Banja Districts, North-Western Ethiopia

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Abstract

This study compares shoot sprouting rate of propagules, height, diameter and growth performance of bamboo culms obtained through different vegetative propagation techniques in Amhara Regional State, where *Yushania alpina* dominated areas of Banja district. The vegetative propagation techniques were rhizome with two nodes, with four nodes, with six nodes, and rhizome without culm and with the offset method (control). In 4 years experiment randomized complete block design with three replications was used. Shoot sprouting, height, diameter and mortality rate data were collected at an interval of six months. There was no statistical significance difference in mean of sprouted shoots of *Y. alpina* between the five treatments. Statistically significance difference was occurred in the mean shoot height between the treatments of rhizome with four nodes and rhizome without culm (137.02b ± 22.94, 67.10a ± 17.97), respectively. Rhizome with four nodes and six nodes had shown significantly higher mean shoot diameter as compared with the traditional one (33.89b ± 12.17, 32.43b ± 12.68, 8.48a ± 2.53, respectively). Mean shoot sprout, and shoot height had shown significance difference with time change. Propagating *Y. alpina* using rhizome with four and six nodes is better as compared with the traditional propagation techniques.

Keywords: randomized complete block design, Yushania alpina, rhizome, vegetative propagation

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1. Introduction

Bamboo is a woody perennial belonging to the family of grasses, *Gramineae (Poaceae)* with unique qualities (Bareja, 2010). It is a self-regenerating and renewable non-timber natural resource. Once established, bamboo is a fast growing and self-sustaining species (UNIDO, 2009). In bamboo growing countries of the world, bamboo is well known as a multipurpose plant with a myriad of application ranging from construction material, furniture, fence, handicraft, pulp and paper, edible shoots and animal fodder (UNIDO, 2010).

According to Banik (1995), bamboos can be propagated either by sexual (reproductive) or asexual (vegetative) means. Sexual propagation is by means of seeds. However, this is not popular in the country due to the irregularity and rarity of flowering of common bamboo species plus difficulties to transport and store seeds. Propagation makes use of different parts of bamboo plants as propagation material. Various methods of vegetative propagation are described by (Hasan, 1977; UNDP, 1995).

Ethiopia has two bamboo species; namely: *Yushania alpina* (formerly named as *Arundinaria alpina*) and *Oxytenanthera abyssinica* covering an area of 31,003 ha and 1,070,198 ha respectively (WBISPP, 2005). The former is growing at steeper and higher altitude while the later is growing lowland parts of the country. Even though, Ethiopia has huge bamboo resources, they are declining at higher rate under pressure from conversion into agricultural fields as well as fuel wood and timber industry. High population growth in the country has increased the demand for food and natural resources and hence the need of additional agricultural land at steeper and higher upland areas. This led to soil erosion and in turn damaged agricultural production.

In response to the above problems Ethiopian government established a new Environment and Forest Ministry, and designed an afforestation and reforestation program to increase the forest coverage of the country. The government promotes planting of bamboo in most regions of the country where steeper and higher uplands are found. Bamboo is well known for its high growth rate, high level biomass production and is environmentally friendly (Senyanzobe et al., 2013). The extensive rhizome-root system and accumulation of leafy mulch make bamboo the most effective in soil erosion control, moisture conservation, embankments reinforcement and drainage stabilization (Zhou et al., 2005).

The indigenous species of Ethiopia (*Yushania a.*) is predominantly found in north-western, south-western, and central parts of the country. Flowering and seeding are required for reproduction and new generations (UNIDO, 2009). However, information about flowering and seeding cycles is lacking for the propagation of this species. In Ethiopia, the indigenous method of farmers in propagating bamboo is the offset method. Offset method makes the use of the rhizomes and the whole portion of culms (Ahlawat et al., 2002). However, constraining problems in using this method are (1) excavating out offsets is cumbersome and labor intensive; (2) offsets are also difficult to transport for long distances because of their heavy weight and long length, (3) excavating out offsets can damage the adjoining rhizome of the neighboring culms. Establishing large scale bamboo plantations by using this technique is very expensive.

Though, the afforestation and reforestation program of the government is constrained by lack of quality and adapted planting materials for this bamboo species. Previous research worked on propagation of bamboo in Ethiopia were not successful in discovering effective techniques; hence further research to test techniques that were not tested well in previous researches is of paramount importance on both lowland and highland bamboo species. Therefore, it is important to develop propagation techniques for effective supply of quality planting material for large scale plantation.

2. Materials and methods

2.1 Study site

This study was conducted in Amhara Regional State, Awi Zone, at Banja district, in the North-West of Ethiopia. This district is located within the distribution range of highland bamboo (Yushania alpina) at 11010’ N and 36015’ E. The altitude of the study area ranges from 1800 to 2953 m.a.s.l.

2.2 Materials

The propagation materials were taken from one-year-old Y. alpina and planted on field through the use of different planting materials: rhizome without culm, rhizome with two nodes, rhizome with four nodes, rhizome with six nodes and offset (control) which is traditionally used by farmers.

2.3 Methods

The experiment was set up for a period of 4 years started as of July 24, 2011 using randomized complete block design with three replications. The sizes of the plots were 36 m^2 and per plot 16 propagules planted with 2 m spacing. The propagation material was used as treatment. The distance used between plots and bocks was 4 m. Shoot sprouting, shoot height, shoot diameter and mortality rate data were collected at an interval of six months each year (2011, 2012, 2013 and 2014).

3. Results

3.1 Number and size of sprouted shoots

3.1.1 Sprouted shoots

There is no significant difference in the mean number of shout-sprouted among the treatment. Time trends shows that there is a significant difference in the mean number of newly sprouted shouts

Table 1: Effects of treatments on sprouted shouts of highland bamboo (data from four years, collected with six month interval)

Treatments	Sprouted shouts	
	Mean	SEM
Offset/rhizome with whole culm	3.24 a	1.48
Rhizome with two nodes	5.81 a	1.7
Rhizome with four nodes	6.9 a	1.5
Rhizome with six nodes	5.71 a	1.58
Rhizome without culm	4.62 a	1.39

Note: SEM= Standard Error of Mean

between seasons (wet and dry), but there is no significant difference between treatments within the season (Table 1; Fig. 1).

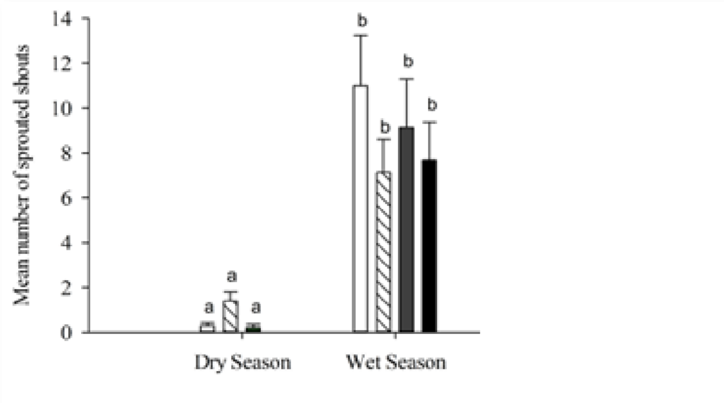

Figure 1: Effects of season on sprouted shouts of highland bamboo (Y. alpina) sprouted shouts

3.1.2 Shoot diameter increment

There is a significant difference in the mean shoot diameter increment between the traditional (offset) and rhizome with four and six nodes propagules. Shoot diameter increment of four and six node propagules were higher than the remaining propagules, but the lowest increment was observed at rhizome without culms (Table 2).

Table 2: Mean diameter increments of the sprouted shoots among the treatments

Treatment	Diameter increment/treatment	
	Mean	SEM
Offset/traditional (control)	8.48 a	2.53
Rhizome with two nodes	28.28 ab	11.57
Rhizome with four nodes	33.89 b	12.17
Rhizome with six nodes	32.43 b	12.68
Rhizome without culm	20.94 ab	8.92

SEM= Standard Error of Mean

There is a significant difference in the mean diameter increment of sprouted shoots between the initial period and with the remaining six periods (Table 3).

Table 3: Effects of time on shoot diameter increments of propagules

Time	Diameter increment	
	Mean	SEM
1	118.91 b	17.94
2	0.34 a	0.2
3	12.96 a	2.16
4	8.21 a	1.84
5	14.54 a	2.65
6	2.10 a	1.49
7	16.59 a	2.85

SEM= Standard Error of Mean

3.1.3 Shoot height increment

There is a significant difference in the mean height growth of sprouted shoots between rhizome with four nodes and rhizome without culm (Table 4).

Table 4: Mean height increment of the sprouted shoots of the propagules

Treatment	Height increment	
	Mean	SEM
Offset/rhizome with whole culm	97.76ab	29.07
Rhizome with two nodes	99.81ab	20.39
Rhizome with four nodes	137.02b	22.94
Rhizome with six nodes	119.48ab	26.11
Rhizome without culm	67.1a	17.97

SEM= Standard Error of Mean

There is also significant difference in the mean height increments of the propagules between March and September (Fig. 2)

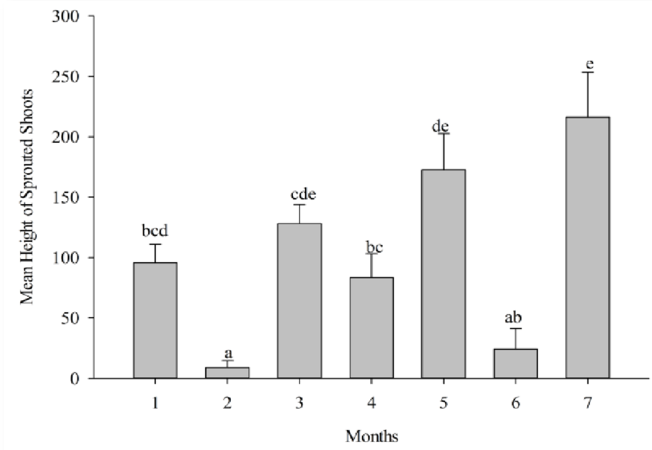

Figure. 2: The mean effects of time on shoot height increments of the propagules

3.1.4 Mortality of shoots

There is a significant difference in the mean shoot mortality between the traditional offset and rhizome without culm propagules. The mean shoot mortality of the offset propagules is zero while the mean shoot mortality rate is higher at rhizome without culm. There is no significant difference in the mean shoot mortality between the other treatments (Table 5). The time trend shows that there is a significant difference in the mean shoot mortality between the offset and rhizome with two node propagules.

Table 5. The mean shoot mortality of highland bamboo propagules

Treatment	Shoot mortality	
	Mean	SEM
Offset/rhizome with whole culm	0.00 a	0.00
Rhizome with two nodes	1.19 ab	0.48
Rhizome with four nodes	1.00 ab	0.49
Rhizome with six nodes	0.14 ab	0.10
Rhizome without culm	1.43 b	0.82

SEM= Standard Error of Mean

There is no significant difference in the mean shoot mortality between other propagules (Fig. 3).

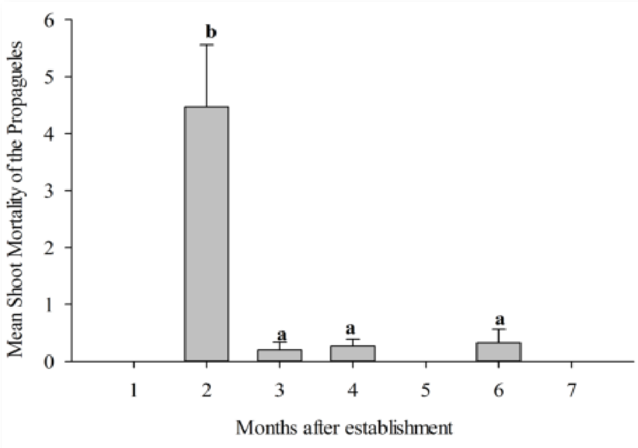

Figure 3. The effects of time on shoot survival rate of highland bamboo propagules

4. Discussion

4.1. Shoot emergency and diameter increment

This study revealed that the sprout of new shoots between the propagules is similar, but the variation of shoot emergence observed between dry and wet season. This evidence is in line with the study of Senyanzobe (2013) that found sprouting rate of shoots after planting varied significantly with different propagules depicted high number of shoots sprout during wet season.

We observed high mean diameter increment in rhizome with four and six nodes as compared with the traditional (offset) method. This suggests that these two propagation techniques are better means for the establishment of large diameter bamboo plants.

4.2. Shoot height and mortality

Shoot height of the rhizome without culm is significantly different from the other propagation techniques. The time trend shows that there is a significant difference in mean mortality of shoots. The traditional one is better in sprouting survival as compared with the other methods of propagation.

5. Conclusion and recommendations

5.1 Conclusion

Propagating by means offset is a traditional method for bamboo propagation. But it is mainly inappropriate for large scale plantation, due to labor intensiveness, time consuming, transportation and other logistical cost. The present finding showed that there is no difference among shoot sprout rate of each propagation material (treatment) whereas, season (dry and wet seasons) have been effects on the shoot sprout rate of each planting materials. On the other hand, the highest and the least shoot mortality was observed on rhizome without culm and offset/rhizome with whole culm respectively. In addition, mean height increment difference was observed in month of September and March. The study revealed that rhizome with six nodes, rhizome with four nodes are best and better alternative means of Ethiopian highland bamboo propagation for large scale as well as small scale plantation.

5.2 Recommendations

Bamboo is one of the most valuable plants nature has given to mankind. But to use its full potential, more fundamental research is needed, to lay foundations for the future bamboo expansion and existence in the country.

- One of the major challenges vegetative propagation techniques for shoot mortality in this research was termite infestations. So further research should be done on treatment applications with different vegetative propagation techniques.
- Vegetative propagation (cutting) is not sufficient methods for huge scale industrial plantation expansion. Further researches are required, like tissue culture and its protocol development.
- Ethiopia has two native species of bamboo (*Arundinaria alpine* and *Oxynanthera abyssinica*). So, the country should adopt other bamboo species which are friendly with the existing native species

to increases the genetic diversity and also more research has to be needed on propagation techniques to boost coverage of bamboo in the country.

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The Performance of GAPAs on Enhancing the Production and Marketing of Gum Arabic Production in West and North Kordofan States, Sudan

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Abstract

Gum Arabic producers associations were established in North Kordofan in 1992, in 2002 the Forests National Cooperation started the establishment of the associations in all productive states in Sudan. The study was conducted in three sites located in the central part of the gum Arabic belt: Alkhawi locality (West Kordofan State), Shiekan and Umrawaba localities (North Kordofan State), with objective to evaluate the performance of gum Arabic producers associations on enhancing production and marketing of gum Arabic. Primary data were collected via questionnaires, field visits, group discussion and direct observations. Secondary data were obtained from documents of relevant institutions and previous studies. Data was analysed using descriptive analysis. The results show that the associations vary significantly in their activities and services they provide for their members. Significant differences are the availability of financial and technical support provided by governmental and non-governmental institutions, and the degree of the association committee awareness and training skills. Members in these associations suffer from the lack of awareness in the responsibilities and duties towards their associations. The preliminary conclusion is that gum Arabic associations without financial or technical support from outside will not be perform services for their members.

Keywords: *Gum Arabic, Gum Arabic Producers' Associations*

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CHAnces IN Sustainability – Promoting Product Chains of Natural Products in Eastern Africa

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Abstract

Natural resource management systems combined with the upgrading of product chains may considerably contribute to a better balance between economic development and nature conservation. Despite the extensive experiences on application of a collaborative management approach, not enough facts are available about potential contribution of natural products and their value chains to rural development. This paper presents a collaborative research project initiated in 2013 for participatory identification and implementation of pilot measures for promotion of three NTFP value chains in Ethiopia and Sudan. The main focus of the pilot measure is development of innovative management systems and upgrading the product chains for three natural resource based commodities in East Africa (bamboo, gum Arabic, incense). The implementation of the research project follows a participatory approach, integrating all relevant stakeholders along the product chain. At levels of production, processing and marketing the research is focusing on (1) sustainable resource management practices, value adding activities and enabling frame conditions; (2) the contribution to livelihoods and rural development; and (3) participation as innovative approach to analyze and develop forest based product chains. In addition to the scientific objectives the project contributes to strengthen the cooperation between partners from research and practice. The research project follows a standardized sequence, organized in 9 working packages, which permits to compare the case studies, learn from best practice cases and draw the lessons learned and conclusions towards applicability for other production systems and product chains. Preliminary findings confirm the participatory approach

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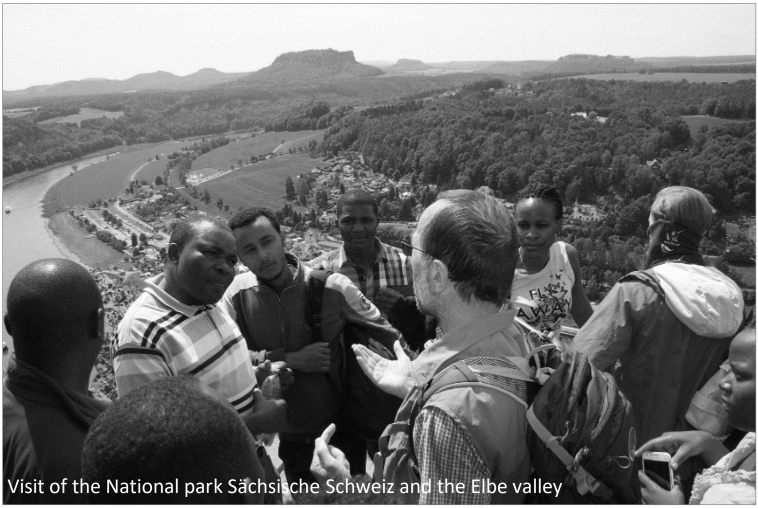
as a successful instrument for stakeholders' dialogue, facilitation of common understanding and identification of priority measures for upgrading the product chains.

Keywords: Value chain, participatory approach, natural gums, Gum Arabic, bamboo, sustainability, Ethiopia, Sudan

Tharandt, view from the castle ruins



Visit of the National park Sächsische Schweiz and the Elbe valley

Biodiversity Conversation and Bioenergy

Land Use, Land Cover and Climate Change Impacts on the Bird Community in and around Lake Zeway, Ethiopia

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African Baobab: Urgent Need for Assessments and Management Approaches for Sustainable Development in Sudan

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Abstract

The paper summarizes information on different aspects of baobab descriptions, its distribution in Sudan and variables which may affect its population development, including effects of climate change and climate variation. Also the effects of land use changes on the baobab tree distribution and productivity are considered. Variation of climate conditions led to unsuitability of the habitat for existence of the baobab trees in some areas. Some land uses are supportive in term of density and productivity of baobab fruits, such as agricultural fields and villages, compared to plains and natural reserves. In the literature studied climate change and land use were described as critical detrimental factors for the existence and production of African baobab trees.

Keywords: literature review, African baobab population, climate change, land use, distribution, *Adansonia digitata*

1. Introduction

In the last decades the attention to non timber forest products (NTFP) has increased worldwide due to their good rapport with environmental intents, including the protection and conservation of biological diversity, and their great contributions to household and national economy and food security (Neumann and Hirsch 2000). In Sudan the population, especially rural, relies essentially on natural resources and services provided by ecosystem. The most of villagers derive their livelihoods out of the forest in form of NTFPs, agricultural activities,

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livestock grazing in natural forest- and rangelands (Devineau et al. 2009, Belem et al. 2007).

Although African baobab is sometimes considered as a “underutilized tree species in Sudan”, its contribution to environmental and socioeconomic development of rural areas is significant. It provides food, fodder, medicine, shelter, and numerous other products and benefits (Gebauer and Elsidig 2002, De Caluwe et al. 2010, Kabore et al. 2011). Baobab gains importance at local scale and gradually becomes popular worldwide: it is introduced at USA and Europe markets. In Sudan, fruits and other products constitute the cheapest source of food for poor people (El Tahir and Gebauer 2004). Here, African baobab is often overlooked by academic researches, as well as by social, economic and development institutions. That is why there is a lack of information about distribution, abundance and productivity of the African baobab in the country.

2. Method and data collection

The procedure of data collection for this literature review followed De Caluwe et al. (2010), Gebauer and Elsidig (2002). Data was obtained from different books, scientific papers, reports and workshops respective conferences proceedings. Terms researched were: land use, climate change, baobab or *Adansonia digitata*; Detailed information about baobab, the effect of land use, and climate change on the species distribution was collected.

3. Results and discussion

3.1 Species description

African baobab (Fig. 1) is a huge deciduous tree, which can reach up to 20 m in height, and 6 – 10 m in diameter. It has a huge, extended root system that stores a big amount of water (El Amin 1990). The bark is smooth, its color varies from reddish brown to grayish white. The leaves are alternate, hand shaped with five sessile leaflets. The flowers are relatively huge, up to 12–15 cm in diameter. They are whitish with large, hairy stamens through which the style protrudes. The fruits are elongated in shape up to 24 cm long and up to 10 cm in diameter, joined to twigs by long stalks. The fruits are greenish-grey when they are juvenile and brownish when mature. The African baobab trees keep leaves just for three months per annum. After dropping the leaves, most of the physiological processes such as photosynthesis continue to take place in the trunk and branches, depending on the water amount stored in the trunk (Gebauer and Elsidig, 2002).

Figure 1: African baobab tree in Sudan

3.2 Baobab distribution

There are eight species of baobab trees in the world; six of which occurs in Madagascar, one in Australia and *Adansonia digitata*, the African baobab, is living naturally in the dry parts of Africa's sub-Sahara.

Adansonia digitata is found in Sudan, Uganda, Kenya and Tanzania. In southern Africa, African baobab is frequently found in Zimbabwe, Malawi, and Mozambique. In the western part, African baobab is found in many countries such as the Ivory Coast, Mali, Benin, Senegal, Burkina Faso and Cameroon (Fig. 2)(Watt and Breyer-Brandwijk 1962, Adesanya et al. 1988, UNCTAD 2005, Lamien-Meda et al. 2008). In Sudan *Adansonia digitata* is found in a belt across the Sahel zone in Blue Nile, Kordofan and Darfur states, with 250-500 mm rainfall per annum (El Amin 1990).

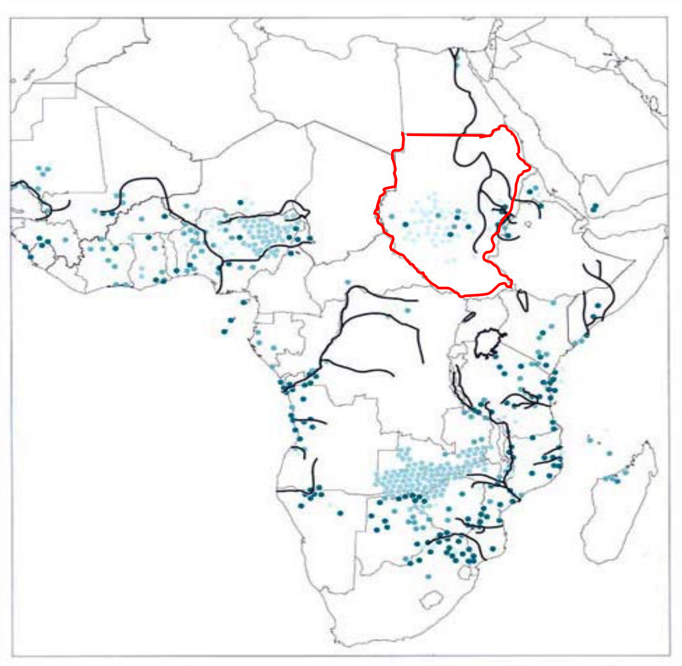

Figure 2: Baobab distribution in Africa

3.3 Land uses and land vegetation cover change

Baobabs grow under different land use types: in outcrops, along river banks, grazing lands, as well as near settlements, where human effect can be pronounced (Chirwa 2006). In many areas the African baobab is used for different purposes and the communities take care and protect the trees. Seedling survival, germination, recruitment and health of trees is better in the fields and villages than in unexploited areas such as plains and fallow areas (Dhillion and Gustad 2004; Duvall 2007).

Venter and Witkowski (2010) studied the productivity of baobab in five land use systems and concluded that fruits production was a little better in fields and villages than in outcrops, reserves, and plains. Moreover, trees size seemed to have an effect on the production of fruits.

3.4 Climate change

IPCC (2007) reported that many evidences of environmental degradation have been recognized in the world at present. More, unreliable and variable pattern of rainfall, which leads to severe drought, is a serious current problem, especially in developing countries. Researchers have concluded that the vulnerability of world areas to degradation covers about 33 % of the world land surface. According to FAO (2005) in Sudan are many signs of environmental degradation reported, also rainfall decrease or fluctuation, changes in climate conditions, and particularly in dry lands. Scientists believe that these issues may affect distribution, recruitment and development of baobab in the dry land. Oladipo (1993), Okorie (2003), and Gonzalez (2010) reported that temperature and precipitation patterns, as well as human practices led to severe land degradation in arid zones. This degradation is manifested in the decline in density and richness of the trees.

Sanchez (2010) found differences in baobab morphology in hot and wet areas. Penman et al. (2010) discovered that the tree with its long life, slow growth and regeneration rate, and seeds low dispersal ability, was the most vulnerable species to any ecological disturbance in the Sudanese ecosystem.

4. Conclusions and recommendations

The review of literature found significant contributions on subjects like climate change, land degradation, and on the baobab species existence, distribution and productivity. More detailed information on baobabs in Sudan is urgently needed for the development of management, utilization and conservation strategies, as well as for safeguards to its environment.

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Ecotourism as Alternative Mean of Biodiversity Conservation and Livelihood Improvement of the Local Community

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Abstract

Ecotourism is an environmentally friendly form of tourism whose activities are carried out in natural setting which in turn promotes environmental understanding. Ecotourism promotion is used as a tool for the conservation of the biodiversity and improve the livelihood of the local community. Ecotourism can help to create jobs for local community and market for local products where by contributing to sustainable conservation of natural resources. Even though meeting the requirements for ecotourism is extremely difficult in developing countries. A research in Bale Mountains National Park investigated the effectiveness of ecotourism in achieving biodiversity conservation and climate change mitigation. This paper argues that, at present, ecotourism can contribute to safeguard biodiversity and ecosystem functions as well as improve community livelihood. Protected areas are biodiversity conservation centers and major tourism assets for a nation, particularly for developing countries like Ethiopia, through providing sustainable benefit to the local community while supporting for the maintenance and rehabilitation of the protected areas themselves.

Keywords: adoption, climate, conservation, ecotourism, community's livelihoods

1. Introduction

Ecotourism is among the fastest growing segments of the travel industry (WTO, 2009) which includes the activities of persons traveling to and

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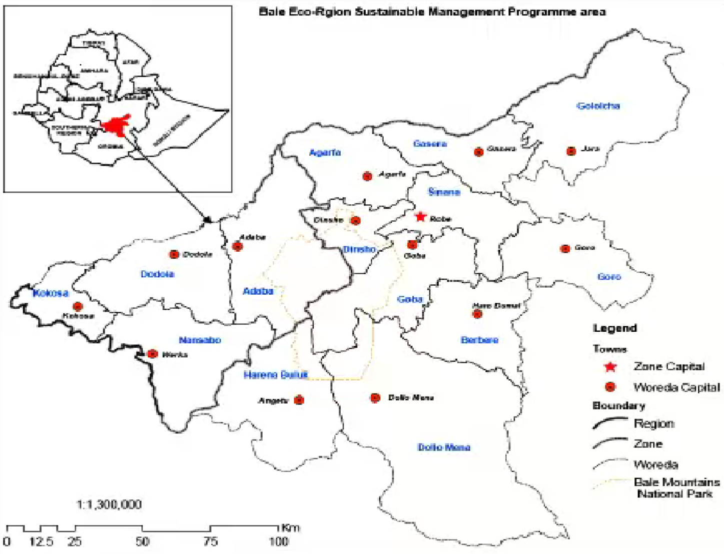
staying in places outside their usual environment for not more than one consecutive year for leisure, business and other purposes (Dabour, 2003). Tourism activity depends on the natural resources or biodiversity. Different activities associated with tourism are often contributed to the degradation of the very natural systems on which the industry itself depends on (Bromhead et al. 2000). Since 1990s the concern on environmental issues has increased and ecotourism has transformed gradually to preferred form of environmentally and socially responsible tourism (Holden, 2003).

Ecotourism is a form of nature-based and environmentally responsible tourism which can support climate change mitigation endeavors by contributing to, and conservation of biodiversity, and creating economic opportunities through diversifying community's livelihoods on a local as well as on a country level (Drumm and Moore, 2002).

Ethiopia possesses considerable biodiversity and natural resource base, particularly noted for its high endemism. However, its human population depends greatly on agricultural activities rather than off-farm income sources like ecotourism (Dagnachew et al., 2003).

Bale Mountains National Park (BMNP) (6°29'-7°10' N and 39°28'- 39°57' E) is located in south east of Addis Ababa, Ethiopia (Fig.1). The Bale Mountains are part of the Bale-Arsi Massif, which forms the western section of the southeastern Ethiopian highlands (Yosef, 2007). The area contains species that are endemic to Ethiopia and species that are found only within the BMNP like the Ethiopian Wolf (*Canis simensis*).

BMNP has a unique natural heritage with outstanding beauty, diverse attractions and great eco-tourism potential. Ecotourism activities are a revenue source for local communities. They developed positive attitude towards the conservation of natural resources and are involved in the reduction of negative impacts like degradation and destruction through conserving the natural resources (water, forest etc.), providing sustainable harvest (farming, fishing, hunting, etc.) and improving residents living environment and quality (Tsaur et al., 2006).



Source: http://www.balemountains.org

Figure 1: Bale mountain national park.

From ecological point of view ecotourism contributes to climate stabilization, ecosystem preservation, and biodiversity conservation (Williams, 2002).

Adaptation to climate change refers to an adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities (IPCC, 2007). As defined by the Convention on Biological Diversity (CBD), biological diversity is “the variability among living organisms from all sources including, inter alia, terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are part, diversity within species, between species, and of ecosystems” (CBD, 1992, Article 2).

2. Objective

The main objective of this review paper is to assess the role of ecotourism in biodiversity conservation, livelihoods improvement of the local community and contribution to climate change mitigation.

3. Ecotourism roles

3.1 The role of ecotourism in biodiversity conservation

Ecotourism is a form of nature-based tourism that strives to protect the environment and to provide incentives for the local communities to conserve nature, and thereby contribute to sustainable development of tourism (Drumm and Moore, 2002; Tisdell, 2003). According to Lowmen (2004) ecotourism follows two important principles of sustainability known as the pillars of ecotourism, namely at promoting natural ecosystem conservation and at supporting the local economy.

Ecotourism is an environmentally friendly form of tourism whose activities are carried out in natural settings that in turn promote environmental understanding. It is often viewed as effective for promoting the conservation of endangered species and habitats in developing countries. By creating economic incentives for impoverished villagers or their communities, ecotourism is thought to encourage local guardianship of biological resources (Wight, 2002; Kruger, 2005).

Ecotourism is also increasingly popular form of tourism in which visitors seek wild and scenic areas such as rainforests or mountains for an active and educational trip. It also becomes popular among people interested in both environmental conservation and sustainable development (Educational Web Adventures, 1996).

Ecotourism is a good way to promote environmental education and awareness to both hosts and guests. By traveling to nature based areas, tourists learn about, appreciate and understand the importance of nature. The more they understand about the environment, the more they contribute to conservation. Accordingly, ecotourism has environmental benefits, if properly managed and applied (Anderson, 1996; Ngece, 2002; Dasenbrock, 2002; Kiss, 2004; Weggoro, 2008).

Ecotourism produces relatively less pollutants than some other industries and can enhance the conservation and promotion of natural resources. When it is properly planned, developed and managed, it has enormous potential to promote conservation based ecosystem management. It is capable of generating benefits like employment and revenue generation to local communities and the public at large (Anderson, 1996; Ngece, 2002; Dasenbrock, 2002; Kiss, 2004; Weggoro, 2008).

As a new conservation approach, ecotourism is supposed to actively entertain the socioeconomic parameters while conserving and developing the biophysical entities of nature (Tadele, 2005). It can provide many opportunities for on-site educational and interpretive programs, which play an important role in conserving natural and rural landscapes and connecting visitors with nature.

Ecotourism seems to be the perfect alternative for biodiversity conservation. It generates foreign currency and income, both locally and nationally and at the same time provides a strong incentive to manage nature's strongholds in a way that would conserve them. Consequently, ecotourism is seen almost as a universal remedy or panacea for the protection of nature (Stiles and Clark, 1989; Burnie, 1994; Gossling, 1999).

Ecotourism is concerned with the maintenance and sustainable development of the natural environment by implementing low impact tourism and is concerned with the benefit of local communities through revenue generation. It is best alternative activity to environmentally destructive activities like farming, logging and mining. Although ecotourism may not be able to preserve these untouched areas as they would if human contact were prohibited, it can help to protect them from the dangers of destructive agricultural practice, mining and industrialization (Anderson, 1996; Ngece, 2002; Dasenbrock, 2002; Kiss, 2004; Weggoro, 2008).

Around the world, ecotourism has been hailed as a mean for economic development and environmental protection. It contributes funding to conservation and scientific research, protecting fragile and pristine ecosystems, mitigating climate change impacts, benefiting rural communities, promoting economic development in poor countries, enhancing ecological and cultural sensitivity, instilling environmental awareness and a social conscience in the travel industry, satisfying and educating the discriminating tourist, and building world peace (Honey 2008).

3.2 The role of ecotourism in improving local community livelihood

The United Nations General Assembly as of 21st of December 2012 has adopted a landmark resolution, recognizing ecotourism as key in the fight against poverty, protection of the environment and promotion of sustainable development. The resolution, entitled, "Promotion of ecotourism for poverty eradication and environment protection", calls on UN Member States to adopt policies that promote ecotourism, highlighting its "positive impact on income generation, job creation and education, and thus on the fight against poverty and hunger". It further recognizes that "ecotourism creates significant opportunities for the conservation, protection and sustainable use of biodiversity and of natural areas by encouraging local and indigenous communities in host countries and tourists alike to preserve and respect the natural and cultural heritage". Ecotourism plays a great role in natural resource management by generating income for the local communities and diversifying their livelihoods (Kiss, 2004).

Ecotourism has high potential to be an instrument for rural economic development and resource conservation. Ecotourism can contribute to economic development and the conservation of protected areas by generating revenues further used to manage protected areas sustainably, to provide local employment, and a sense of community ownership. To be successful, ecotourism should promote conservation of natural resources and provide financial gains for the host country and the local people. However, without careful planning and management that balances ecological, social, and economic objectives, ecotourism can easily cause environmental damage (Schaller, 1998).

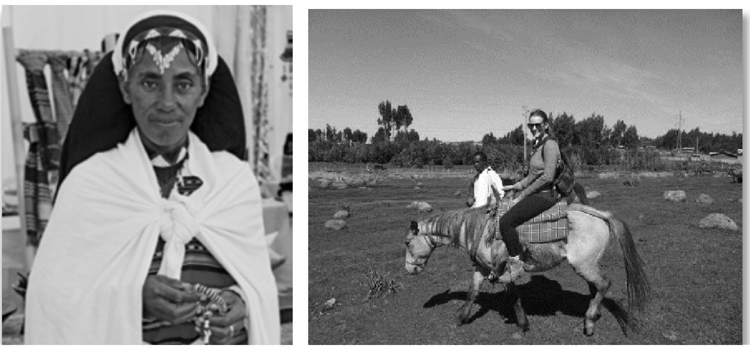
3.2.1 Employment and creating of new jobs opportunities

Ecotourism plays an important role in creating employment in many countries with one out of every 16 new jobs worldwide in the sector providing 50 million jobs in developing countries alone (Ulack and Casino, 2010).

Ecotourism brought employment opportunities to often previously disadvantaged people and a significant amount of the industry remains in the form of small-scale projects that can be funded by locals. Since the sector is labor intensive, its expansion generates more employment opportunities at all semi skilled, technical and managerial level than an equivalent expansion in other sectors of the economy (Anderson, 1996; Koeman, 1998; Dasenbrok, 2002; Ngece, 2002; Lowmen, 2004; Weggoro, 2008).

Local communities have started benefiting from activities such as working as rangers, tour guides, environmental interpreters or camping staff in these same areas and creating local businesses focusing on transport, providing food, crafts and entertainment (Fig.2) for foreign tourists (Adapted from Courvisanos and Jain, 2006).

Ecotourism stimulates profitable domestic industries like hotels and other lodging facilities, restaurants and other food services, transportation systems, handicrafts, guide serves etc. Ecotourism plays a great role in achieving the Millennium Development Goals (MDGs) (UNESCO, 2007:8).



Source: www.balemountains.org, www.panoramio.com

Figure 2: Ecotourism as source of employment

Ecotourism supports the economics of poor tourism destinations through increased local employment and income, more regular employment and income throughout the year, greater diversification of economic activities, thereby reducing economic risks and opportunities for locally controlled ecotourism related business (Tisdell, 2003).

3.2.2 Source of foreign currency

Ecotourism has assisted poor countries to gain greater economic independence through foreign earnings (Scheyvens and Momsen, 2008). It can be a good source of income for indigenous populations if it is applied using appropriate mechanisms (Eslami and Roshani, 2009).

Tourist expenditures on lodging, transportation, food, guides and souvenirs are important sources of income for local communities by providing supplemental income to rural farmers, women and young people. It is a relatively decentralized industry that is highly capable of diversifying regional economies of less developed countries, which are dependent of primary activities (Anderson, 1996; Koeman, 1998; Dasenbrok, 2002; Ngece, 2002; Lowmen, 2004; Weggoro, 2008).

Ecotourism provides direct financial benefits for conservation, brings economic benefits to local communities and direct revenues to local people living adjacent to protected areas, employs locally and facilitates the flow of money back to the community (Lowmen, 2004; Kiss, 2004).

The benefits accruing from investment in infrastructure and superstructure as airports, hotels and restaurants, road networks, communications, power and water supply as well as other related public utilities are widely shared with other sectors of the economy, resulting in to greater economic efficiency. Tourism (Fig 3.) is an excellent means for transferring income from wealthy nations and persons to the poorer sections of society (Anderson, 1996; Koeman, 1998; Dasenbrok, 2002; Ngece, 2002; Lowmen, 2004; Weggoro, 2008).

Source: www.balemountains.org,

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Figure 3: Barre woman and Ethiopian traditional handicraft

3.3 The role of ecotourism in mitigating climate change

Climate change mitigation relates to technological, economic, and social changes and substitutions that lead to emission reductions (IPCC, 2007). Mitigation can be realized through technological innovation and market mechanisms, but significant reduction in greenhouse gases (GHG) emissions can be achieved through behavioral change like, for example, increasing number of tourist service provider change to less polluting vehicles. Under such scenarios, ecotourism in natural resource conservation might also contribute to climate change mitigation. Conservation of natural resources prevents environmental degradation. Because of this, ecotourism has received global attention. (Yadav, 2002).

Supporting and regulating ecosystem services provided by protected areas are important for mitigating climate change. An estimated 15 percent of the terrestrial carbon stock is currently held in protected areas. Protected areas are critical for further carbon emissions caused by degradation, therefore ecotourism activities provide an important contribution to an overall strategy for climate change mitigation by expanding and improving the management of the protected areas (Yadav, 2002).

Tadele (2005) stated that the existence of ecotourism has contributed greatly to the conservation of an area’s natural resources (forests, soil, water), by indicating that highly degraded and bare-soil areas, which have been rehabilitated a few years ago, attracting now more and more birds and wildlife, improving the microclimate and became recently an engine for attracting tourist.

3.4 Negative impact of uncontrolled ecotourism

Provision of benefits to communities adjacent to protected areas through ecotourism is an important environmental conservation tool. Tourism in natural areas often places considerable stress on the environment, such as erosion, noise and air pollution (Okech and Bob, 2009).

Negative impacts from ecotourism occur when visitors use is greater than the environment’s ability to cope with that within acceptable limits of change. Uncontrolled tourism poses potential threats to many natural areas around the world. It might put enormous pressure on an area and lead to soil erosion, increased pollution, discharges in the water, natural habitat loss, increased pressure on endangered species and vulnerability to forest fires (Anderson, 1996).

A number of studies shows that the impact of hikers hiking with heavy loads and horses makes more damages to the trails and vegetation during wet seasons. Such damages take longer time for recovery and if the trails are used repetitively, the recovery is almost impossible in a defined period that clearly affects the ecology of the destination (Cole, 2004).

While concerns about tourism's polluting effects cover all aspects of a tourist's activity, the primary issue is the greenhouse gas (GHG) emissions generated through travelers’ transport (notably road and air transport), and energy consumption in tourism establishments like air conditioning, heating, lighting in hotels.

4. Conclusion

Natural resources in developing countries are under great threat. People affect the ecosystem due to lack of alternatives, lack of means, lack of economic activities and their livelihood strategies. The pressure on natural resources could be minimized by diversifying their livelihoods with more eco friendly activities. In line with this idea, ecotourism as alternative economic activity enables both to diversify livelihoods and to manage natural resources sustainably.

Ecotourism has a great role in biodiversity conservation, in diversifying local livelihoods and in climate change mitigation. Ecotourism can help economic development and conservation of protected areas by creating local jobs, providing a sense of community ownership, and bringing in revenue for the sustainable management of protected areas. If local communities directly benefit from the use of their land, water, forests and other natural resources, they can be expected to support and participate in efforts to conserve and sustain them. Thus ecotourism projects should aim to increase socioeconomic benefits to communities and landowners; sustainably manage the environment, raise awareness of and support for conservation, increase a community's capacity to conserve and manage natural resources outside protected areas, and diversify the livelihood of rural communities.

5. Summary

Ecotourism is an important source for economic uplift. In addition to this, it facilitates community development, poverty eradication, employment opportunities and direct income of local community. Ecotourism, a recent but widely hailed tourism alternative has high potential to be an instrument for rural economic development and resource conservation. Ecotourism can contribute to economic development and the conservation of protected areas by generating revenues that can be used to sustainably manage protected areas, and by providing local employment and a sense of community ownership. Community-based ecotourism, if well-established, can play a reasonable role in community development and can bring people closer to conservation. One of the essential elements of ecotourism is the encouragement of active participation of local population in the conservation process, and careful consideration should be made to the distribution of benefits of ecotourism amongst people. Ecotourism is used to conserve biological diversity, which in turn mitigates climate change through increasing the resilience of ecosystems, which can enhance and reduce the risk of damage to natural ecosystems through the adoption of biodiversity-based adaptive and mitigation strategies.

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The Role of Wood Fuel in Climate Change: A Case of Urban and Rural Areas in Uganda

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Abstract

Uganda derives over 80% of its domestic energy from wood fuels, particularly charcoal in urban areas and firewood in rural areas. Households, small and medium scale industries form the biggest market for these products. Despite its size, the biomass energy sector is still understudied. This study evaluated the wood fuel situation in both rural and urban areas and its role in climate change in Uganda. The study determined and compared the levels of wood fuel use in rural and urban areas, and assessed the contributions of rural and urban wood fuel consumption to Uganda's CO_2 emissions. The findings of the study show that, rural areas used more wood fuel than their urban counterparts and emitted more carbon dioxide emissions than urban areas. It is recommended that sustainable technologies should be promoted to ensure sustainable use of wood fuels and provision of better alternative sources of energy.

Keywords: biomass resources, sustainable development, fuel efficient stoves

1. Introduction

Warming in the last 100 years has caused about 0.74^{o}C rise in global average temperature (IPCC, 2007) consequent upon the accumulation of greenhouse gases in the atmosphere such as carbon dioxide ($C0_2$), methane (CH_4), nitrous oxide ($N0_2$), water vapor (H_20), nitrogen trifluoride (NF_3), chlorofluorocarbon (CFC), among others. Increase in the levels of greenhouse gases in the atmosphere, now 440 ppm from

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310 ppm during pre-industrial times has mainly been due to anthropogenic causes (WMO, 2014), with burning of fossil fuels constituting 11.3%, energy generation 26%, deforestation 17%, industry 19%, and agriculture 14% of carbon dioxide emissions. Whereas the bulk of GHGs emissions are from industrial nations due to extensive use of fossil fuels like coal and petroleum (Statterthwaite, 2009), the developing countries such as Uganda contribute to GHGs emissions especially through energy use, agriculture, and deforestation (McSweeney et al., 2008; UNDP, 2013).

Uganda like any other sub-Saharan African country derives most of its energy from biomass (Bailis, 2010). It is estimated that over 90% of the household energy is derived from biomass resources (Bizarri, 2009). Most of this energy is used for cooking in combination with other sources of energy such as electricity and liquefied petroleum gas (LPG) (GOU, 2007; UNDP, 2013). Charcoal being predominantly used in urban settings (about 70% of the urban population), while firewood is more common in rural areas (about 86% of the rural population) (Basu et al., 2012). This is attributed to the fact that alternative sources of energy like electricity are more expensive which is leaving the countries biomass resources like forests as the “cheapest" and the only remedy to the country’s ever rising energy demands (Basu et al., 2012). As a consequence, with one of the primary causes of deforestation being wood utilization for fuel, Uganda’s forest cover has continually diminished from 11 million hectares in 1890 to less than 4 million hectares in 2005 (GOU, 2007). This increased deforestation and wood fuel use has therefore risen volumes of greenhouse gases into the atmosphere. As a result, changes in climate patterns resulting in extreme conditions like floods, heat waves and drought have been observed. This study was carried out to evaluate the wood fuel situation in rural and urban areas of Uganda with emphasis on levels of wood fuel used and resultant carbon dioxide emissions.

2. Study area

The study was carried out as to case studies, one in urban and one rural area of Uganda. Nakaseke district (Ngoma sub-county) represented the rural area while Kampala (Luzira) represented the urban area of Uganda.

Both districts are found in the central region of Uganda. Table 1 shows the distinguishing features of the two study areas.

Table1: The comparative features of the two study areas

Feature	Ngoma, Nakaseke	Luzira, Kampala
Location	Latitude: 0.301667^0 Longitude: 32.644999^0	Latitude: 0.3003^0 Longitude: 32.56489^0
Annual rainfall	Less than 1125 mm. Peak rain perio ds: Mar-May, Oct- Nov	Average 1174 mm. Rainfall seasons: Mar-May, Sep-No v
Temperature	Max. temperatures 18^0 – 35 ^{0}C, min . 8^0 – 25 ^{0}C	Annual range 17 -27 ^{0}C
Altitude	1210 m above sea level	1155 m above sea level
Population	Sparsely populated	Highly populated
Main energy for cooking	Firewood	Charcoal
Vegetation/ Land cover	Grass savanna with dry *Combretum*	Residential use and small scale agriculture.
Topography	Generally hilly	Generally hilly
Economic activities	Agriculture, charcoal burning, herding.	Business, small scale urban agriculture

Source: DEFRA (2002)

3. Method

Case studies were carried out in Kampala and Nakaseke districts of Uganda. For each district, one sub county was randomly selected, Luzira for Kampala and Ngoma for Nakaseke. Within each selected sub county, two villages (Safina 1 and 2 for Luzira; Kamusenene and Gomero villages for Ngoma) were randomly selected. “Random walk and skipping rule” was used in each sample area to select households. A total of 60 households, 30 for urban and 30 for rural were used in the study. For carbon dioxide emissions, estimates were made by multiplying the amount of wood fuel used with emissions conversion factor. The conversion factor allows the amount of wood fuel used to be converted into kilograms of carbon dioxide equivalent (a unit of measurement that allows the global warming potential of different greenhouse gases to be compared). The amount of charcoal used was converted to an equivalent of firewood since only the conversion factor for firewood was available for the study.

4. Field data collection

Data were collected in July 2013. Using a weighing scale, the weight of wood fuel used was determined. Charcoal and sun dried firewood were weighed (households used sun dried firewood since it is easy to light and burn easily). This was done on a daily basis for 30 days to give an estimate of the monthly household wood fuel consumption. Before taking the weights, the households were contacted and the purpose of the study was explained as purely scientific and academic and for ethical reasons it was emphasized that the data will be treated with confidentiality and anonymity. In addition, households were interviewed on the number of people living and eating in that household, the number of guests received in a given time period and that was used to determine the average number of persons in a household.

5. Data analysis

To compare levels of wood fuel consumption, daily weights of the household's wood fuel consumed were pooled together to get the mean daily household wood fuel consumption in each area. The per capita values for wood fuel consumption for each area were determined by dividing the average household wood fuel consumption with average number of people per household.

The amount of wood fuel used was determined using a weighing scale (measured in kilograms) and the conversion factor that matched the fuel measurement unit was identified. The amount of wood fuel used was then multiplied by the conversion factor to get the total emissions in kilograms of CO_2 equivalent. However, emissions accruing from the transportation of the wood fuel and emissions from the production of charcoal in the kilns were not considered. To determine the contribution of rural and urban area wood fuel consumption to Uganda's CO_2 emissions, Uganda's population was approximated to be 37.5 million (UNDP, 2013) and given that 86% (32 m) of the population is rural (Oxfam, 2012), the number of rural households was projected to be 4.5 m households. The urban area constituting 14% (5.5 m) of the country's population was projected to have 1,375,000 households. According to Rupert (2010); DEFRA (2012); DECC (2012), 1kg of wood fuel when burnt produces approximately 1.725 kg of CO_2 emissions. Thus, 6.2 kg of wood fuel consumed daily by urban households amount to 3.9 t of CO_2 annually while rural households emit 7.7 t of CO_2 annually with their daily wood fuel consumption of 12.3 kg. Per capita values for rural and urban residents are 1.1 and 0.96 t/person/year respectively (Oxfam, 2012). From extrapolations, rural Uganda emits 30.8 metric tons of CO_2 in household wood fuel consumption considering that 86% (Oxfam, 2012) of the rural population uses woodfuel. On the other hand, urban Uganda emits 3.3 metric tons of CO_2 in household wood fuel consumption considering that 70% (Oxfam, 2012) of the urban population entirely relies on wood fuel.

6. Results

6.1 Level of wood fuel use in rural and urban areas

The level of wood fuel use differed significantly between the urban and rural areas ($P<0.05$), rural households used more wood fuel than the urban households. The average household consumption in the rural areas was 12.3 kg/household/day, while that in the urban households was 6.2 kg/household/day. The amount of wood fuel consumed by rural households showed higher daily variations than the consumption pattern exhibited by urban households (Fig.1). Daily charcoal consumption in the urban areas ranged from 0.4 - 5.4 kg/household/day whereas that in the rural areas ranged from 3 - 35 kg/household/day. The average number of people was seven persons per household in rural areas whereas that for urban areas was four people per household. The per capita values for wood fuel consumption were 1.76 kg/person/day and 1.54 kg/person/day for rural and urban households respectively.

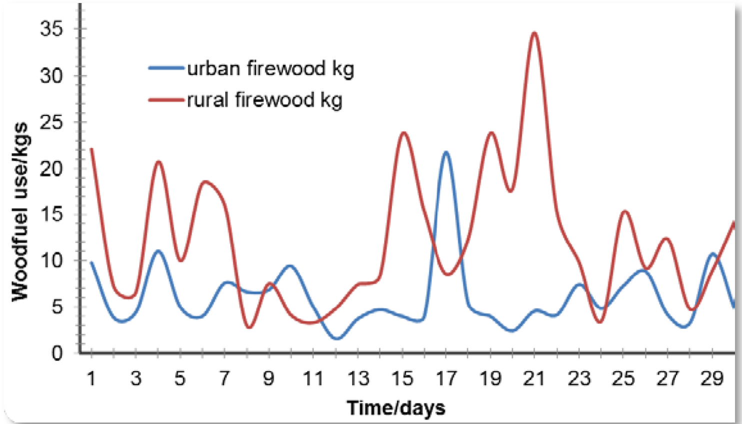

Figure 1: The daily variation in wood fuel consumption

6.2 The contribution of rural and urban area wood fuel consumption to Uganda's CO_2 emissions

The wood fuel consumed by an urban household amount to 3.9 tons of CO_2 annually, with a daily wood fuel consumption of 6.2 kg: A rural household emits 7.7 tons of CO_2 annually with a daily wood fuel consumption of 12.3kg. The rural Uganda emits 30.8m tons of CO_2 in household wood fuel consumption while urban Uganda emits 3.3m tones of CO_2 in household wood fuel consumption. Total CO_2 emissions from household wood fuel consumption for rural and urban households amount to 34m tons of CO_2 annually.

7. Discussion

7.1 Variation in daily wood fuel consumption

Daily wood fuel consumption varied in both rural and urban areas. This is due to daily changes in household sizes as result of influx of visitors, social activities like parties that result into changes in food types and quantities prepared. Therefore, wood fuel consumption peaked when the number of household increased and decreased when the number of households reduced. The variations can also be attributed to the daily changes in fuel wood billets sizes and types used. According to Tabuti et al., 2003, big pieces of firewood go off when left to burn while small pieces burn to ashes hence creating the variations in the amount of firewood used

7.2 Level of fuel wood consumption in rural and urban areas

The levels of wood fuel consumption were significantly different for rural and urban areas, with the rural areas using more amounts than the urban areas. This is because rural households have almost an unlimited access to wood fuel most especially firewood. To most of the households, the firewood is free - apart from family labor to collect it. This result lends support to Bizarri (2010) who noted that rural households consumed more firewood because they had easier accessibility. Similarly, the amount of charcoal used in urban areas was found to be lower than that of rural areas, partly because urban dwellers sometimes use alternative sources of cooking (electricity and gas). The impossibility of burning charcoal and firewood in the flats of residence in urban areas also explains the difference in the amounts of wood fuels used. Therefore, the difference in the amounts of wood fuels used can be attributed to the difference in cooking habits and types of food prepared between rural and urban households. Also, the types of stoves employed in the rural and urban areas undoubtedly contributed to the observed difference in wood fuel consumption in these two areas. Urban households used high efficiency stoves and thus less fuel to prepare their food as compared to the rural households that mainly used the three stone stove with a very low efficiency, thus more fuel consumed. Habermehl (2007) reported, that improved stoves were supplied to both rural and urban areas of Uganda, through the urban communities welcomed the stoves, the rural communities was reluctant in adopting adopt the novel technology thus retaining their wasteful stoves that consume more than twice the wood fuel amounts consumed by the improved stoves. The per capita values for wood fuel consumption were nearly the same for rural and urban households. This indicated that the larger the household, the lesser the wood fuel that was consumed individually. This finding is consistent with a survey conducted by Oxfam (2012).

7.3 The contribution of wood fuel consumption to Uganda's carbon dioxide emissions

Rural areas contributed the bulk of CO_2 emissions as compared to their urban counterparts. The majority (86.7%) of the population in Uganda lives in rural areas and 90% of these people use wood fuel which is abundant, free, and accessible. The higher dependence on wood fuels for their domestic activities thus explains the soaring CO_2 emissions from these areas as compared to the urban areas where the people do not depend entirely on wood fuel but use other energy sources like hydroelectric power.

8. Conclusion

The level of wood fuel consumption differed between rural and urban households, whereby rural households used more wood fuel than the urban ones. The per capita values for wood fuel consumption in rural and urban areas were 1.76 kg/person/day and 1.54 kg/person/day respectively. The rural areas contributed more carbon dioxide emissions from wood fuel consumption than urban areas. The average per capita emissions of an average rural resident from wood fuel consumption (1.1 tones CO_2 per person per year) was found to be higher than that of an average urban resident (0.96 tones of CO_2 per person per year). The total annual CO_2 emissions from wood fuel consumption at household level (34.1 million tons) are higher by a factor of 10 than those from fossil fuel use and cement production (3.7 million tons), which is often used as a benchmark for a nations' CO_2 emission. It is recommended to promote sustainable technologies, including sustainable use of wood fuels, sources of cooking energy with lesser CO_2 emissions, fuel efficiency stoves etc., to reduce the amounts of wood fuel consumed by households and thus the levels of carbon dioxide emissions from wood fuel consumption.

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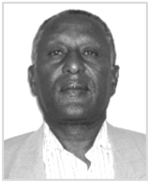

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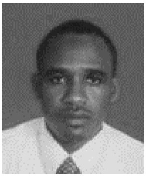

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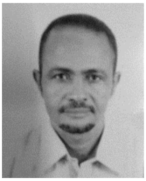

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