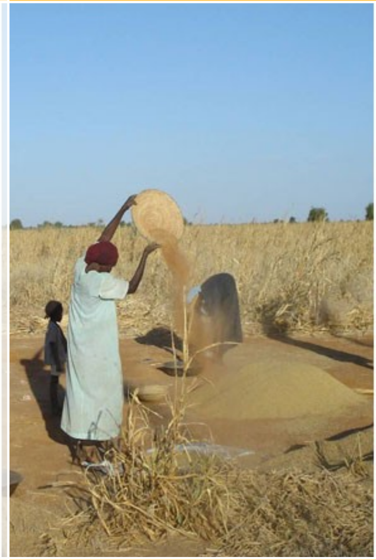
Welcome to Africa

Proceedings of the Summer-School Workshop

2013



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

4 – 12 March 2013

Khartoum / El-Obeid, Sudan

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This publication is a compilation of the papers presented at the annual network meeting and Summer-School of the project “Scientific Cooperation Network on Climate Change Adaptation” within the DAAD “Welcome to Africa” program.
The workshop took place from March 4th – March 12th 2013 at the University of Khartoum and University of Kordofan, Sudan.

We thank all presenters and authors for their participation and fruitful contributions. Particularly we want to highlight the enormous efforts of the Sudanese network papers to make the event a success.

Scientific Cooperation Network on Climate Change Adaptation

Project Summary

1. Introduction

In sub-Sahara African countries land use practice is dramatically affected by the consequences and effects of climate change. Recent droughts and changed rainfall patterns demonstrate that climate change is not a phenomenon to deal with in future – it is already there (Conway and Schipper, 2011). Extreme weather events are influencing both, ecological processes, and local communities by the impacts on usable land, crops and livestock (Lovett et al., 2005, Dressa and Hassan, 2009, Blackwell, 2010).

Scientific research on such adaptation strategies needs to be intensified, and existing experiences have to be communicated in scientific networks (Conway and Schipper, 2011). Special emphasis has to be put on the qualification and sensitizing of university lecturers as drivers for further research in national universities and research centers. In this context trees and forestry can play a very important role by providing a huge spectrum of functions and services, which are beneficial for regional value chains and the livelihood of local people (Conway and Schipper, 2011).

Special emphasis has to be put on the creation of trans-disciplinary research, teaching and training networks; facilitating the cooperation between local farmers, scientists and students. Such networks have to serve as platforms for mutual learning, knowledge creation, transfer and interchange by following an adaptive and collaborative strategy.

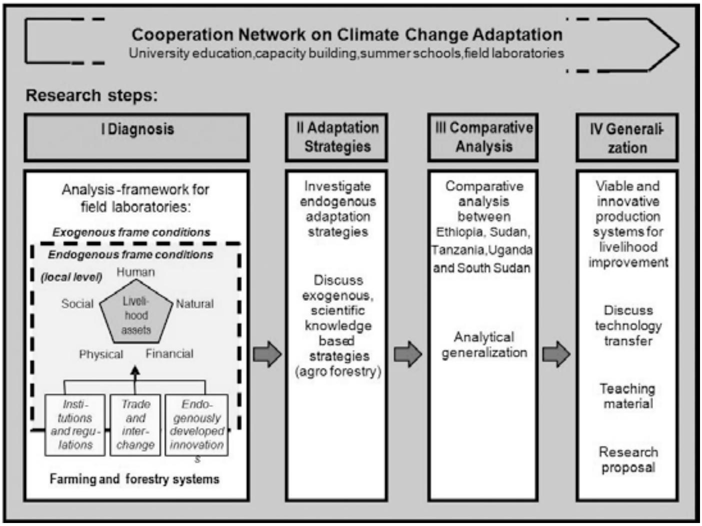

Figure 1. The general framework and research steps of the Scientific Cooperation Network on Climate Change Adaptation

2. Objectives and Outcome

Three main objectives are established for the network:

i. Investigate climate change effects, identify local climate change adaptation strategies, and reveal innovative technologies for an effective climate change adaptation

ii. Share the gained knowledge within higher learning and research institutions of Sub-Saharan Africa and Germany and develop their capacity in climate change related teaching and research further

iii. Elaborate a common research project on climate change adaptation and mitigation

The outcomes of the network activities are expected to have multiple benefits in three dimensions: academic, scientific and developmental.

Academic:

- Professional capacity of African and German students and junior scientists (BSc, MSc and PhD studies level) further developed
- South-North/North-South and South-South cooperation strengthened
- Common teaching module and respective material on climate change and climate change adaptation designed and tested (min. 10 credit points)
- Research network in partner countries strengthened

Scientific:

- Research results from BSc, MSc, PhD studies and Postdoc research
- Knowledge exchanged and synthesized in annual summer school workshops
- Joint publications with research results in international peer reviewed journals submitted (minimum 3 per year)
- Proposal for an integrated research project on climate change adaptation and mitigation designed and submitted

Developmental:

- Awareness on local climate change adaptation strategies created in case study areas
- Experiences shared between farmers and scientists, and promising technology solutions discussed and extended
- Support material for policy makers established

3. Partner

The organization of the cooperation network on climate change adaptation follows the principle of transparency and low complexity. In each partner institution one coordinator has been nominated, who has the full responsibility for the partner institution's part. The project coordinator takes over the management of the complete network.

In a first stage seven partners from Ethiopia, Germany, Sudan, Tanzania and Uganda will form the network, in a later stage it will be extended by an institution from South Sudan.

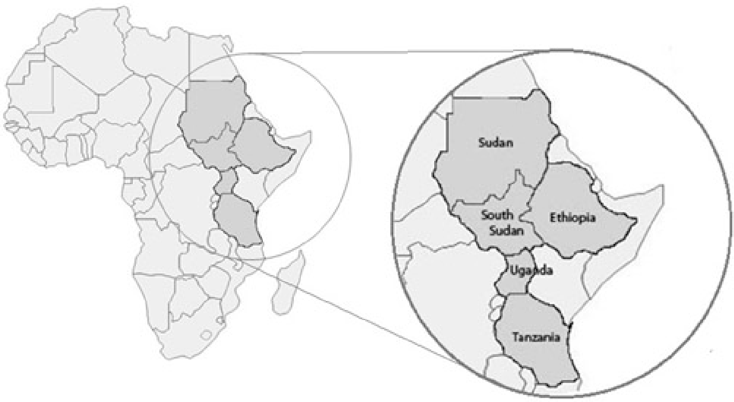

Figure 2. Home countries of involved African partner institutions

4. Funding Instruments and Project Activities

Coordination

- Organization and managing of project activities, communication with partners and persons exchanged, monitoring, administration of project funds, and reporting
- Coordinating and strengthen the network

Material

- Support for the network activities of the African partners

Summer school workshops

- Platform for communication and exchange within the network
- Planned for each year in Africa and in Germany
- To present and to discuss current research on climate change adaption strategies

- Research and climate change related field excursions
- Annual meeting of representatives of all partner institutions to work on administrative and organizational issues

Coordination visits

- Maintain and build the cooperation network
- Contact potential partner

Study and research visits

- By African senior scientists and postdocs and German Postdocs, PhD- BSc- MSc Students
- Focus on climate change effects and adaption strategies
- Guest research and studies within a partner institution
- Guest lectures and teaching within a partner institution
- Work on joint publications
- Elaboration of a common teaching module
- Elaboration of a joint research proposal

5. References

Conway, D., Schipper, E.L.F. (2011) Adaptation to climate change in Africa: Challenges and opportunities identified from Ethiopia, in: Global Environmental Change, 21, 227–237.

Lovett, J.C., Midgley, G.F., Barnard, P. (2005) Climate change and ecology in Africa, in: African Journal of Ecology, 43, 167–169.

Deressa, T.T., Hassan, R.M. (2009) Economic Impact of Climate Change on Crop Production in Ethiopia: Evidence from Cross-section Measures, in: Journal of African Economy, 18, 529–554.

Blackwell, P.J. (2010) East Africa's Pastoralist Emergency: is climate change the straw that breaks the camel's back?, in: Third World Quarterly, 31, 1321–1338.

Introduction on
Climate Change Adaptation

Elements of a Research Agenda for Climate Change Adaptation of Local Communities

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Abstract

The contribution deals with methods and instruments to assess natural resource based development potentials and challenges in rural areas and to make the step from diagnosis to action. An additional challenge is climate change adaptation. Special emphasis is put on the reflective character of rural development processes. The implementation of socio-economic a field laboratories and scenarios development are suggested as tool for the diagnosis. Action has to follow a holistic and communicative strategy. Some elements are discussed and an outlook is given.

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1. Introduction: Challenges for rural areas and land use in tropical countries

Rural areas are worldwide under transition. On one hand there is an increasing demand for food production from urban centers. Land scarcity leads to competition between production systems for food, biomass for energy and the provision of the numerous of environmental services like recreation, biodiversity conservation or water provision (Bizikova 2011). On the other hand rural areas are getting less attractive especially for young people because of the lack of qualified job opportunities and the low level of infrastructure. One of the consequences is “brain drain” to urban areas. Land use units increase in size and mechanization level with low employment opportunities. This leads to the depopulation of rural areas. Still open is the future of small, family based farms (McMichael 2006). These are of high importance for subsistence and the provision of food for urban areas. But they have to compete with large production units.

Additional challenges appear from climate change, which especially affects the situation in rural areas and from the liberalization of international market, which are increasingly volatile. Often production and commercialization outcomes from agriculture and forestry are hardly foreseeable, which makes primary production less attractive for the rural population. The assessment of rural areas, production systems and recently climate change adaptation strategies of the local population needs to be based on local knowledge as well as on modern innovations (Lindner and Pretzsch 2013).

All actions and innovations have to fully fit in the difficult ongoing life of rural people. All changes have to intrinsically come from them, being rooted in their livelihood strategies (Carney 1998). Instruments have to be developed to guarantee this. The elements which have to be taken in account are represented in Figure 1 in socio-ecological coevolution model.

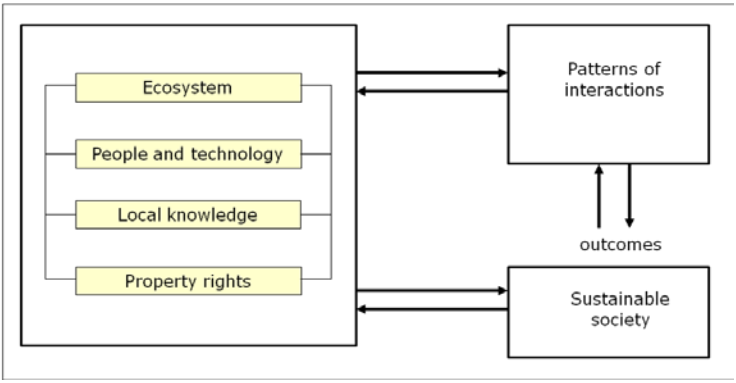

Figure 1: A framework for the analysis of the link between social and ecological systems for resilience and sustainability. (Berkes, Folke, Colding 1998, 15)

2. Need for a holistic and action oriented methodology

Conventional scientific approaches need to be enlarged. They must include knowledge and interests of the rural population. Problems and solutions have to be assessed together with all affected stakeholders. Analytical science approaches are oriented towards the control of the environment and do not permit to understand the complexity of the permanently changing human-ecological systems. Hermeneutics and qualitative ethical studies permit a much farer reaching insight and are relevant for the understanding of the systems (Pretzsch 2001).

Early approaches from cultural ecology explained socio-ecological systems, taking in account complex interrelations (see figue 2). As Bennet (1976, 18) points out, “At the heart of any attempt to deal with ecology from the standpoint of social policy lies the question of whether society itself becomes an “environment” comparable to the natural environment. ...But the issue has theoretical ramifications as well, largely because of the cognitive ability of the human mind to assimilate the properties of Nature into the domain of Culture.”

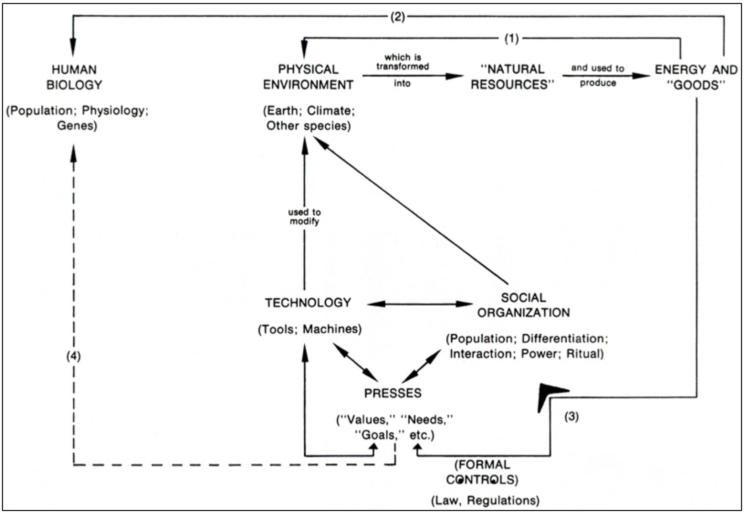

Figure 2: A paradigm of human (or cultural) ecology, emphasizing the output function (cited from Bennet 1976, 38)

Furthermore a third dimension action orientation is essential. It is embedded in the critical theory and in action research. The involvement of all three dimensions, control, understanding and action requires the application of flexible methodologies. Constructivism is a relevant epistemic approach to combine the three level levels (Berger & Luckmann 1967; Röling 1993, 1995). Proposing a power-free dialogue, Habermas (1965, 1988) discusses conditions for the implementation a respective ethical approach.

Forestry and other land use related disciplines have even more to open up towards social and philosophical sciences. Beside this the investigation process has to take in account the reflective character of socio-ecological systems. An adaptive management approach has to be implemented to capture the non-linear development of the system.

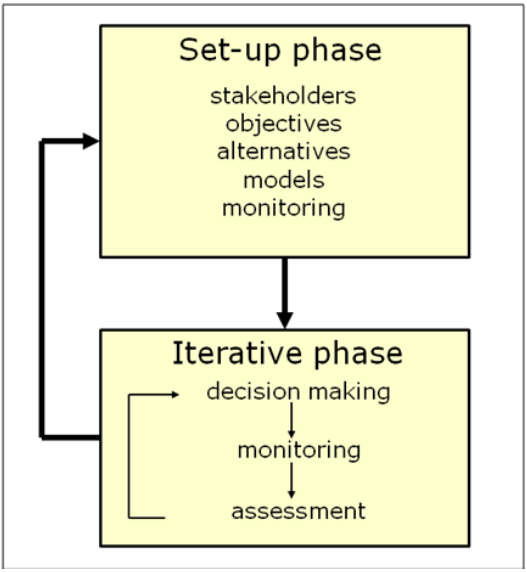

Figure 3: Two-phase learning in adaptive management (Williams 2011, 1348)

The model of Williams (2011) demonstrates the iterative and extremely dynamic process of a diagnosis of rural socio-ecological systems as well as of any innovation in rural development.

3. An innovative diagnosis instruments

The assessment of land use in rural areas, its dynamics and potentials of production systems requires qualitative instruments, which take in account the local knowledge and the historical determination of the local population. Perceptions with the three components of cognitive, affective and experience based driven influences, have to be understood and integrated in the diagnosis and in designing action (Eagly et al. 1993). In various projects socio economic field laboratories have been developed and tested, which permit to take up local knowledge and perceptions of the rural population towards innovations and change (Rist 2011). Field laboratories are a platform for “knowledge exchange” between local land users, scientists, students, NGO members and other relevant stakeholders. The fundament for “understanding” the reality, are discourses and common action. Traditional knowledge systems are experienced and documented together and solutions are outlined. A strong familiarization with the local historical and cultural aspects is a precondition and all relevant stakeholders have to be involved in the field laboratory. After analyzing local knowledge and traditional livelihood strategies it is essential to enter in a discourse on changes and innovations. Often the implementation of modern knowledge is proposed by local stakeholders and the discursive interchange of knowledge has to be accompanies by common implementation trials of the new technology (Pretzsch & Domke 2014).

Picture 1: Field laboratory about the perception of biodiversity in Bolivia

Of special importance is interdisciplinary and inter-sector knowledge and learning, because the farms are rather complex units. The typical Western preference for commodity orientation has to be given up and care has to be taken to take in account traditions, religious customs, informal institutions and the broad bundle non-market values related to nature.

Scenarios represent an additional very useful type of research instrument, which permits to perceive perceptions about the future and which is of importance, especially in climate change adaptation research (Moll & Zander 2006). Beside its importance to "triangulate" the information which was accumulated in the first phase of the laboratory, scenarios are essential in designing development paths and action.

4. From diagnosis to action

Resulting from a profound diagnosis, field laboratory participants may vote for action. Diagnosis as well as action involve and require "learning" of all community members as well as it carries risks of misunderstanding and failure. Before the implementation of new technologies, often innovations in the organizational capacity are required. This may be related to the further development of "social capital" inside the community as well as related to external links between the community and other actor groups. Often the development of innovative organization schemes is required, as for example the renovation of cooperatives and associations, based on the needs of the communities. Further action may be focused on the improvement of production systems by technical innovations like the implementation of agroforestry systems, better training by adequate extension services or a better allocation of different income sources. Here increasingly off farm income has to be taken in account. The same relevance has the upgrading of the value chain of natural resource based products or services, which may be related to simply better technologies in the product chain, a better distribution of the value added or even the improvement of access rights along the chain (Poschen et al 2014; Ribot 1998). All together this may lead to “stepping up” or even “stepping out” of the cycle of disinvestment and poverty (Dorward et al 2005).

5. Revalorize rural areas

Rural regions are in a difficult situation, on one hand there are strong incentive from the increasingly globalized markets to enlarge production units, which goes hand in hand with an outmigration of rural people including small scale farmers. At the same time it is very important to prepare rural area to take over even more functions in an increasingly urbanized world. Thus it is of prior importance to keep options open for the future, especially in the field of resource availability and resilience capacity. The focus on a positivistic and technology oriented position has too long blocked an open discourse on future visions for forestry (Pretzsch 2001). That means, it has to be accepted, that a paradigmatic shift towards a more constructivist understanding of the social reality of forestry is essential (Escobar 1988, 1992). Much more common experimentation in socio-economic field laboratories is suggested to investigate tailor made development solutions in rural areas. This involves the creation of a better image of the potential of rural development and authentic local forestry strategies.

References

Becker, D.; Ostrom, E. (1995) Human ecology and resource sustainability: The importance of institutional diversity. Annual Reviews Ecol. Syst. 1995, Vol. 26: 113-133.

Bennet, J. W. (1976) The Ecological Transition: Cultural Anthropology and Human Adaptation. New York et al., Pergamon Press.

Berger, P.L.; Luckmann, Th. (1967) The social construction of reality. A treatise in the sociology of knowledge. Doubleday and Middlessex

Berkes, F.; Folke, C.; Colding, J. (1998) Linking social and ecological systems. Cambridge University Press, Cambridge.

Bizikova, L. (2011) Understanding the Contribution of the Environment to Human Well-Being: A review of literature. IISDReport, International Insitute for Sustainable development, Winnipeg.

Borrini-Feyerabend, Grazia; Farvar, M.Taghi; Nguinguri, Jean C.; Ndangang, Vincent (2000) Co-management of natural resources: organising, negotiating and learning-by-doing. GTZ and IUCN, Kasparek Verlag, Heidelberg.

Carney, D. (1998): Implementing the Sustainable Rural Livelihoods Approach, London, UK: Overseas Development Institute. Available at: http://www.dfid.gov.uk/public/what/advisory/group6/-rld/dianakey.html

Dorward, A.; Anderson, S,; Nava, Y; Pattison, J.; Paz, R.; Rushton, J. Sanchez, V. (2005) A guide to indicators and methods for assessing the contribution of livestock keeping to the livelihoods of poor. Dept. of Agricultural Science, Imperial College, London, UK

Eagly, A.; Chaiken, S. (1993) The psychology of attitudes. Forst Worth: Harcourt Brace Jovanovich.

Escobar, A, (1988) Power and Visibility: Development and the Intervention and management of the Third World. Cultural Anthropology, Vol. 3, Issue 4, pp. 428-443.

Escobar, A. (1995) Encountering development, Princeton.

Grimble, R.; Wellard, K. (1996): Stakeholder methodologies in natural resource management: a review of principles, contexts, experiences and opportunities. Paper presented at the ODA NRSP Socioeconomic Methodologies Workshop, 29–30 Apr, 1996, London, UK.

Groot de, R. S. (1992) Functions of Nature. Evaluation of nature in environmental planning, management and decision making. Wolters-Noordhoff.

Habermas, J. (1965) Erkenntnis und Interesse, S. 1139-1153, in: Merkur 213.

Habermas, J. (1988) Theorie des kommunikativen Handelns. Bd. 1 und 2, Frankfurt.

Lindner, A.; Pretzsch, J. (2013) An international network on climate change impacts on small farmers in the tropical Andes - Global conventions from a local perspective. In: Sustainable Agriculture Research 2(2): 92-98.

McMichael, P. (2006) Peasant prospects in the neoliberal age. New Political Economy, II, 3, 407-417.

Moll, P.; Zander, U. (2006): Managing the interface. From Knowledge to Action in Global Change and Sustainability Science. Oekom Verlag, München, 157 S.

Plummer, R.; Armitage, D. (2007) A resilience-based framework for evaluating adaptive co-management: Linking ecology, economics and society in a complex world. In: Ecological Economics 61 (2007), 62-74

Poschen, P. et al. (2014): Creating Rural Employment and Generating Income in Forest-Based Value Chains. In: Forests and Rural Development. Berlin, Heidelberg, Springer-Verlag.

Pretzsch, J. (2005): Forest related rural livelihood strategies in national and global development. In:Forests, Trees and Livelihoods, 2005, Vol. 15, pp. 115-127.

Pretzsch, J. (2006) Methodological Aspects of Tropical Forest management Research. Contribution to the World Forest Congress, 9 p. Available at: http://www.fao.org/DOCREP/Article/WFC/XII/0791-C4.HTM.

Pretzsch, J.; Domke, M. (2014): Steps towards a Green Economy: Knowledge Generation and Management in Tropical Forestry. In: Transdisziplinär und Interkulturell. Technikphilosophie nach der akademischen Kleinstaaterei (2014). Band 1, Würzburg, Könighausen&Neumann.

Ribot J (1998) Theorizing Access: Forest profits along Senegal's Charcoal commodity chain. Dev Chang 29:307-341.

Rist S, Boillat S, Gerritsen P, Schneider F, Mathez-Stiefel S, Tapia N (2011) Endogenous knowledge: Implications for sustainable development. pp 119-146 in Wiesmann U (ed) with an international group of coeditors Research for Sustainable Development: Foundations, Experiences, and Perspectives. Perspectives of the Swiss National Centre of Competence in Research (NCCR) North-South. University of Bern, Bern, Switzerland: Geographica Bernensia, Berne.

Rist, S.; Chiddambaranathan, M.; Escobar, C.; Wiesmann, U. (2006): "It was Hard to Come to Mutual Understanding..." The Multidimensionality of Social Learning Processes Concerned with Sustainable Natural Resource Use in India, Africa and Latin America. In: Systematic Practice and Action Research 19(3): 219-237.

Walker, B.; Carpenter, St.; Anderies, J.; Abel, N.; Cumming, G.; Janssen, M.; Lebel, L.; Norberg, J.; Peterson, G. D.; Pritchard, R. (2002) Resilience Management in Social-ecological Systems: a Working Hypothesis for a Participatory Approach. In: Conservation Ecology 6 (1):14. Available at: http://www.consecol.org/vol6/iss1/art14.

Williams, B. (2011) Adaptive management of natural resources – framework and issues. In: Journal of Environmental Management 92 (2011) 1346-1353.

Investigation of Rain Water Harvesting Techniques as a Copy Strategy to Climate Change in the Sudan

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Abstract

The aim of this study was to investigate the contribution of water harvesting techniques (haffir and terrace system) to the sustainable livelihood of local communities at rural areas in Sudan through improving living conditions of pastoralists and farmers, and strengthen their resilience to climate change. Two types of data was used in this study namely, primary data and secondary data. The former was collected through interviews and group discussions with key informants and primary stakeholders (farmers and pastoralists) and the latter was collected from the archives of some Non-governmental Organizations. The main findings of the research are; haffir (hand dug depression) and terraces (water micro-catchment) are the most common types of water harvesting techniques in Sudan and contribute to availability of drinking water to people living in villages or those living nomadic life. Among those who suffered most are the nomad pastoralists who historically used to move their herds freely searching for water and pasture. Dependence on scarce and erratic rains represents great risk to livelihood in rural areas. In North Darfur and Kassala states, the terrace system contributed significantly to enhancement of the resilience of local communities as indicated by comparing the livelihood before and after adoption of intervention. Haffir in North Kordofan and Gedarif states contributed significantly in mitigating natural resource-based conflicts associated with water

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shortages. The main barriers for the adoption of the intervention at a large scale are; ecological barriers (rain intensity, quantity and distribution), social and cultural barrier (awareness and attitudes), and financial barrier. The main conclusion drawn from the operational hypothesis of the study is that water harvesting can respond, on the ground, to climate change adaptation needs for vulnerable groups.

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1. Introduction

Sudan total area is over 250 million hectares, much of which is comprised of arid lands and desert. Sudan lies within the tropical zone between latitudes 3o and 22o N and longitude 22 o to 38o E. Overall, the country's land and water resources can be classified into arid and semi-arid ecosystems, savannah ecosystem on clay soil, and savannah ecosystems on sand soil (GoS, 2007). Throughout much of the country, water resources are limited and drought is common. These conditions create a situation in which Sudan is already highly vulnerable to current climatic shocks and will become even more vulnerable in the face of future climate change (Balgis and Sanjak, 2004). Rainfall, which supports the overwhelming majority of the country's agricultural activity, is erratic and varies significantly from the northern to southern ranges of the country. The unreliable nature of rainfall, together with its concentration in short growing seasons, heightens the vulnerability of Sudan's rain-fed agricultural systems. The far northern part of the country typically experiences virtually no rainfall. In the central area south of Khartoum the rainfall averages about 200 mm/year. Variability in rainfall may reach about 50% in the northern half of the country and 30% in the central region. On the other hand, Sudan is blessed with substantial water resources represented in the Nile River and its tributaries (Abdul galil and Rabish, 1998).

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. The agricultural sector is dominated by small-scale farmers who are living in conditions of persistent poverty and rely on rain-fed and traditional practices. This combination renders them highly vulnerable to climate variability (HCENR. 2003). Indeed, chronic drought is one of the most important climate risks facing Sudan, threatening the existing cultivation of about 12 million hectares of rainfed mechanized farming and 6.6 million hectares of traditional rainfed lands (GoS. 2012). Pastoral and nomadic groups in the semi-arid areas of Sudan are also affected by the frequent drought cycles and erratic nature of rains. Sudan's diverse agro-ecological zones and abundant surface water offers the potential to produce a range of crops and livestock (GoS, 2007). Yet, production is quite low because the agricultural system is not well adapted to rainfall variability and prolonged drought events (HCENR. 2003). Moreover, in rural areas, people living in villages or nomadic life, suffer from drinking water shortage for themselves and their livestock due to the absence of water storage facilities. Lack of water affected very much the socio-economic life of the rural people and compels many of them to migrate to urban centers. Dependence on scarce and erratic rains represents great risk to livelihood in rural areas. There, water scarcity is the single most impediments for development and stability (GoS. 2012). Practice has shown that techniques for water harvesting gave good results in storing rainwater. Rain water harvesting technology is one of the priority for rural socio-economic development in the country (GoS, 2007). It is cheap to develop with high socio-economic returns which are represented in enhancing availability and access to water, improve living conditions of pastoralists and farmers, promote peace and stability, and strengthen the resilience of the local communities to climate change. Different types of Water Harvesting techniques are used in Sudan like simple embankments (terrace system), small surface impoundments (Hafir), embankments on seasonal water courses for agriculture/drinking, embankments on khors or streams to increase infiltration rates for ground water recharge, and small dams, embankments with some structures (HCENR, 2003).

The starting premise of this study is to highligh the role of terrace and haffir systems in the sustainable livelhiood of locala communities across the arid and semi arid zones of the Sudan. The study focuses on these systems because they are adopted by the local people in the rural area for centures, affordable and cheeper compared to other rainwater harvesting (RWH) methods which require hydrological and topographical. The aim of this study was to investigate the potentiality of (RWH) technology in enhancing the sustainable livelihood of local communities in the rural area of the Sudan, and enlighten the main barriers for the diffusion, transfer and adoption of the technology. North Darfur, Gedarif and Kassala states were selected to represent the semiarid zone which is characterized by a limited amount of rainfall (GoS, 2007).

2. Methodology

A site visit was made for data collection to the study area (North Darfur, Gedarif, Kassala and North Kordofan states). Different methods of social survey were used for the collection of the primary data (face-to-face interviews, group discussion and observations). The first step of data collection started with initial identification of stakeholders in order to involve these groups actively in the assessment of the impact of rain water harvesting technology on the sustainable livelihood of local communities. While the identification of key informants was made to mobilize them to play the role of garnering communities trust and cooperation. The group discussion and interviews were made of a series of open questions, followed by more specific questions depending upon the responses to the open questions. The selection of this method is justified by; its simplicity and possibility of assembling the stakeholders through invitation in one place, the necessary data can be collected in a relatively short time, and the method is suitable for data collection and validation of findings since all the members of the group discussion have the right to raise opposing arguments where it is valid.

3. Results

3.1. North Darfur State

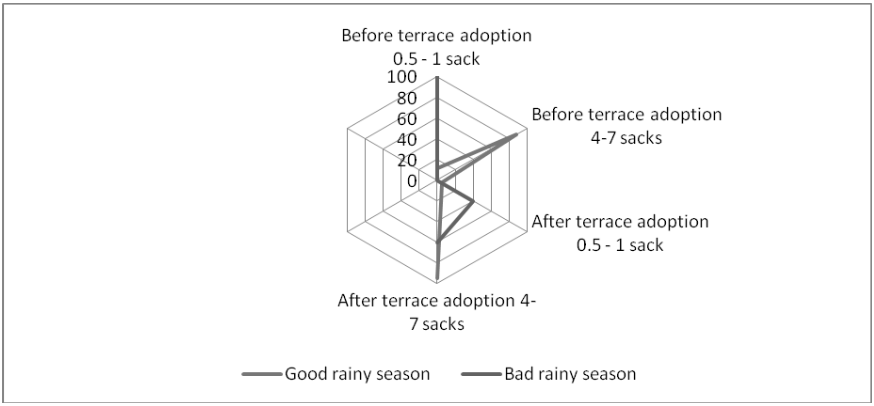
Historical development of terrace system

Under the situation of unpredictable rainfall, decline in crop productionl, rain fed farming has become increasingly risky in the state as asserted by the entire interviewed sample. In year 1964 farmers managed to practice cultivation close to wadi El Ku (seasonal water course running from the highlands of Jebel marra) using the terrace system. Great yield was attained and all the farmers in the state become motiviated to adopt the intervention. The terrace system consists of the cultivated land which is bunded on three sides, and a catchments located at the open side upslope of the cultivated land. Sanjak (2004) indicated that the terrace system increases and conserves soil moisture for plant growth by capturing and conveyancing of rainwater to the arable land. Eighty-five per cent of the respondents stated that some NGOs contributed to the development of the terrace system in the study area.

Agricultural production

In the past farmers used to cultivate Millet (*Pennisetum typhoides*), Sorghum (*Sorghum bicolor)* as subsistence crops, besides okra (*Hibiscus esculentus*) and karkadeh (H. *sabdariffa*). The production in good rainy years fall within the rang of 4-7 sacks per mukhamas (one mukhamas equivalent to 1.75 feddan) as mentioned by 88.3% of the respondents (Fig 1). The rest of the respondents harvest less than 4 sacks per mukhamas. While the productivity during the bad rainy years drop to 1 or ½ sack per mukhamas as stated by 47% of the respondents. Adoption of the terrace system enhanced agricultural productivity dramatically. In good rainy years farmers harvest >12 sacks per *mukhamas* as asserted by 75.6%, while in bad rainy season the productivity under terrace system is 4-7 sack per mukhamas as accentuated by 69%. Twelve per cent of the interviewed sample stated that even during the bad rainy season they are able to harvest more than 12 sacks per mukhamas. The entire interviewed sample asserted that the contribution of the terrace system to the resilience of local communities is apparent because now farmers can practice farming during summer and winter. Moreover, the terrace system increased employment opportunities, securing family food supplies and health needs and safeguarding children's education by meeting school fees.

Figure 1: Comparison of agricultural productivity in North Darfur State



Animal resources

Livestock breeding is traditionally the second occupation in the state. Before the adoption of the terrace system about 26.7% of the respondents asserted that it is not common to witness big herds of livestock due to the deterioration of the rangelands and armed robbery of the livestock. The adoption of the terrace system provides the chance for cultivation along the seasonal water course through blocking the channel allowing the water to spread along the two banks. This result in enriching the natural rangelands with fodder particularly during summer time and contributed to the settlement of many pastrolists particulary under the civil war conditions. This finding is supported by 86.7% of the respondents. Moreover, availability of agricultural residues across the year contribute to diversification of nourishment.

Comparison of income from water harvest and rainfed cultivation

It is extreme difficultly to collect reliable data on incomes because farmers are not statistically minded and do not keep proper records of income and expenditure. Given the conditions described above, income generated from both systems is small, but income generated from terrace system is much better compared to past cultivation. The majority of the respondents (53.3%) claimed that their income from rainfed cultivation falls within the range of 610000-800000 SDG (a dollar is equevillant to 5.69 SDG), while 15 per cent showed it falls within the range of 400000-600000 SDG. Under the terrace system, 66.7% of the respondents claimed that their income exceeds 4110000 SDG. This finding indicates that the gross income from water harvesting is much better than that obtain from goz cultivation. On the other hand, comparison of savings between the terrace and old system takes the same pattern where 41% of the farmers under the terrace system showed that they may save more than four millions SDG in good rainy season, while 21% of the respondents asserted that they could save between 35000-500000 SDG in years of good production. These findings offer the opportunity to evaluate the contribution of water harvesting technique to the resilience of local communities. Farmers under this system are potentially capable to invest in agriculture and gain considerable revenue which could be exploited in raising the standard of living and rural development. The situation before the adoption of the intervention reflects the vulnerability of the local communities to variation in income generation where the agricultural production lags far behind the ambition of the farmers to gain reasonable profit to support their lives.

3.2. Kassala State

Historical development of the terrace system

Kassala State falls with the semi arid zone and is characterized by erratic nature of rains. Rains are fluctuating with long period of episodes and frequent drought cycles. The terrace system is autonomous based on local knowledge. The system involves digging out a narrow trench, and throwing the soil uphill to form a ridge. The measures are simple and easily mastered. The cost is low, labor and the renewal of worn-out hand tools are the main expense for the farmers. The majority of the respondents (94%) asserted that Practical Action Organization developed the technique of the terrace system through introduction of cresent shape terrace and the pond former (a mchine bound on tractor) construct the terrace in a relatively short time (100m per minute). Since the area is a desert prone area, production is not stable across years. Some years have exceptionally high production while some others have low production. As a result, the entire interviewed sample accentuated that their livelihood is much better compared to prior terrace system adoption. The terrace system contributed significantly to the increase of crop productivity as asserted by the entire interviewed sample. The majority of the respondents (95%) indicated that through the terrace system it is possible to increase the productivity from 1–1.5 sack/per feddan to 4–7 sacks/per feddan. It worth mentioning that, before the adoption of the terrace system, 76% of the respondents stated that it is difficult to harvest more than 2 sacks per mukhamas, and during the bad rainy season the productivity decline to nill or one sack per muckhamas (Fig 2). They attributed this increase in productivity to the guarantee of moisture contents retention for a long period.

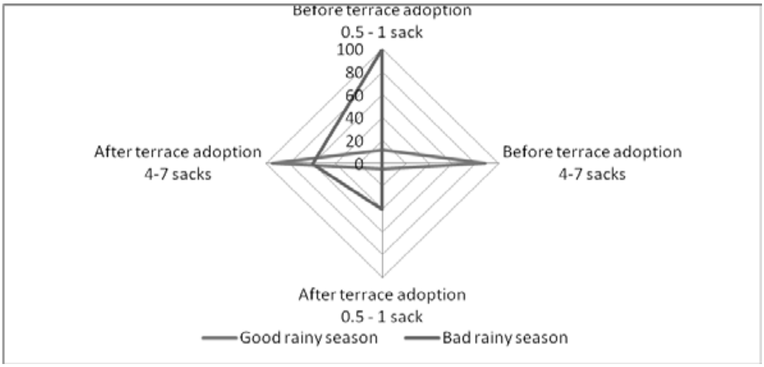


Figure 2: Comparision of agricultura productivity in Kassala State

Animal wealth in the state

Eighty per cent of the interveiewed sample asserted that the terrace system contributed to rehabilitation and enrichment of natural rangelands. Eighty-five per cent asserted that before the adoption of the system the rangelands deteriorated and many preferred species lost their dominance. With the adoption of the terrace system the vegetation cover showed successful restoration which in turn reduced the tribal conflicts over natural rangeland as asserted by 92% of the respondents. The entire interviewed sample stated that the natural rangelands improved signigicantly under the terrace system.

3.3. Gedarif State

History of haffir development

At Samturk - Gedaref State, Practical Action Oranization in close coordination with Higher Council of Environment and Natural Resources (HCENR)-Elgadarif, excavate natural depressions for sake of improving natural rangelands in the state through avaoiding inundation of the agricultural schemes and the natural rangelands. Rainfalls are sporadic and drought takes place every 3–5 years. Therefore, it is a common unwelcome visitor to the state and induces several negative impacts. Ninety-two per cent of the interviewed sample asserted that the depressions played substantial role in mitigating conflicts between pastrolists and settlers from one side, and among pastrolists. Moreover, the entire respondents accentuate the increase agricultural productivities. Seventy-five per cent of the interviewed sample asserted that in the past rain water accumulates at the depression during the rainy season. Therefore, it hinders the agricultural activities in the agricultural schemes, but after the deepening of the depression the productivity of the agricultura schemes increased dramatically. Moreover, the inundated fields restrict the mobility of agricultural machineries and livestock. The pastoralists stated that after the deepening of the natural depression they used to stay for a long period compared to the past where they get in conflicts which may escalate to disputes with other pastrolists as a result of competition for natural resources.

Natural Resources

Practical Action in coordination with Forests National Corporation – El Gedarif State launched afforestation program at the project area. The interviewed sample stated that the afforestation and reaforestation around the depression showed outstanding success and this guarantee availability of fodder partiuclary during summer. It is well known that acacias trees provide livestock with fodder during summer time.

3.4. North Kordofan State

Historical Development of Haffir

Water harvesting is an old story in the state. The state acts as a catchment for rain water coming fromNuba mountains. The combined flow of seasonal streams represents the main source of water in the state. The flow varies considerable from one year to another following the erratic nature of the rainfall in the region. Most of these streams are not monitored regularly. There are famous surface storage depressions in North Kordofan state, but the small depressions (haffir) are of parmount importance compared to large depressions as indicated by the interviewed sample.

Settled farmers and pastoralists are vulnerable groups to climate change and variability in the state where there is consistent gradual decline in mean rainfall. Shortage of water supply in course of nomad stock routes is very common in the state, especially during dry season. Traditional dugouts or natural depressions fed by rainwater and run-off (Hafirs) play a critical rolein North Kordofan State in supplying water for domestic use in villages and to pastoralists in remote areas, as percieve by the entire interviewed sample. Due to increasing competition over limited water supplies in the state, many Hafirs have become 'flashpoints' between pastoralists and farmers. The major problem that faces the rain fed farmers is drinking water after the rainy season especially during the harvest time. Ninety-two per cent of the interviewed sample stated that a hafir, that used to hold adequate water for the 4-6 months of dry season, now would hardly suffice for 2 months of dry season due to siltation and lack of maintenance. The entire interviewed sample asserted that in order to reduce the chance for natural resource-based conflicts, there is a need to rehabilitate the old haffirs and digout new ones.

Barriers to Technologies (haffir and terrace system)

The respondents mentioned the main barriers confronting diffusion, transfer and adoption of the terrace and haffir systems at large scales. The main barriers were, as percieve by the respondents; ecological barrier (fluctuations of rainfall), lack of financial funds, lack of human technical skills, scarcity of technical know-how, policy and regularity barrier, and awareness barrier: - Social barrier (Insecurity in some areas

4. Conclusions

The main conclusions drawn from this study are; it is possible to adopt the interventions of terrace and haffir systems at large scale since they are cheap compare to other RWH methods. Moreover, their impacts are positive on the local communities living at rural marginalized areas.

References

Balgis O. and Sanjak, E. (2008) Livelihood and drought in Sudan. In: Leary N., Conde C., Kalkarrai J., Nyong A.and Pulbin J. (ed.). Climate Change and Vulnerability. EarthScan UK and USA.

Balgis O. et al. (2008) Community Development and Coping with Drought in Rural Sudan. Leary N., Adejuwon J., Barros V., Burton I., Kulkarni J. and Lasco R. (ed.). Climate change and Adaptation. EarthScan UK and USA Field manual for agroforestry extension. 2003. High Commissioner for Refugees.

GoS (2007) National Adaptation Programme of Action. Republic of Sudan, Ministry of Environment and Physical Development. Higher Council for Environment and Natural Resources. Sudan.

GoS (2012) A report prepared by Shouraconsult for DIU. Directorate General of Projects. Water Harvesting Directorate. Dams Implementation Unit (DIU). Ministry of Electricity and Dams. Sudan.

HCENR (2003) Sudan's First National Communication Under the United Nations Framework Convention on Climate Change (UNFCCC), Khartoum.

Leary, N. et al. (2008) A stitch in time: General Lessons from Specific Cases. In: Leary N., Conde C., Kalkarrai J., Nyong A.and Pulbin J. (ed.). For whom the Bell Tolls: Vulnerabilities in a changing Climate. Climate change and Adaptation. EarthScan UK and USA.

Leary, N. et al. (2008) Livelihood and drought in Sudan. In: Neil Leary, Cecilia Conde, Jyoti Kalkarrai, Anthony Nyong and Juan Pulbin (ed.). For whom the Bell Tolls: Vulnerabilities in a changing Climate. EarthScan UK and USA.

Sanjak, E. (1996) Community forestry and participation of local people. *Journal of Community forestry,* 20. Sofia, Bulgaria.

Sanjak, E. (1996) Monitoring and evaluation of private forests in Greece. *Journal of Community forestry* 20. Sofia, Bulgaria.

Sanjak, E. (2004) Environmental Strategies for Increasing Human Resilience in Sudan: lessons for Climate Change Adaptation in Northern and Eastern Africa. Water Harvesting in Central Darfur, Sudan.

Sanjak, E. and Rudwan, M. (2005) Water Vulnerability: A Desk Based Review O Relevant Literature On Impact, Vulnerability And Adaptation To Climate Change In The Agriculture and Food Security Sector, Khartoum, Sudan.

Sanjak E., Balgis O. and Nagmeldin E. (2008) Food shortages in North Darfur State, Sudan: a consequence of vulnerability to drought. www\\ttt aiacc.org.

Community Based Adaptation Strategies to Mitigate Drought Impacts in Um Eshera Administrative Unit, North Kordofan State, Sudan

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Abstract

North Kordofan State is one of the areas, in the Sahelian Zone of Sudan, that severely affected by the recurrent drought episodes which hit the Sahel since seventies of the last century. Agriculture, mainly subsistent farming represents the main form of livelihood in the area. Natural resource base, in this part of the country, is vulnerable to environmental changes and combined effects of drought and desertification. The situation is further aggravated by increase in rural population and unfavorable socio-economic conditions which forced local communities to develop some strategies that mitigate the effect of those adverse conditions. The present study was designed to investigate adaptation strategies tailored by subsistent farmers, in Um Eshera Administrative Unit, to endure the impact of drought. Political ecology approach was used and data were collected using structured questionnaire targeted 92 farmers randomly selected and interviewed. Chi squire test and regression analysis were used for data analysis. Results revealed that local people have developed assortment of adaptation mechanisms and strategies for alleviation of drought effects. The most important strategies were dry sowing (Ramail), traditional rainfall forecast (Eleana), intercropping and increasing seed rate.

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The study concluded that the adopted mitigation strategies were significantly contributed to sustainability of the farming system, and improvement of livelihood in the area.

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1. Introduction

Sudan is located between latitudes 8º and 22 º N and longitudes 22 º and 38 º E, in the northeastern part of Africa. The surface area of Sudan is 1,882,000, Km2 (Badri, 2012). North Kordofan State, a semi-arid area in mid-west Sudan, lies within the savannah zone between latitudes 9º 5' and 11º 7' N and longitudes 27º and 32º E. It is the main producing area of gum arabic, and it spouses the largest gum arabic market in the world in its capital Elobeid. Administratively, the state is divided into 9 localities (Figure 1), comprising about 33 administrative units. The population is 3,200,000. Traditional rain-fed agriculture is the main form of livelihood. Bush fallow, is the typical farming system in the area of Kordofan, where field crops are cultivated for several years until soil fertility decreases, forcing the farmer to abandon the land and a new forest area is cleared for crop production (El Samani, 1986). A typical practice of the traditional bush fallow system involves a 20 year's rotation during which Acacia senegal tree is grown for 15 years, agricultural crops (millet, sesame, sorghum and groundnut) are grown for 5 years followed by 5 years of young unproductive Acacia senegal, which later produce gum. Controlled grazing is practiced after the trees reach the age of four years or after the gum has been harvested in case of productive trees (Cossalter, 1991). These traditional bush fallow systems, are predominantly Acacia based and are common in the African Sahel (Ballal et al, 2005; Raddad, 2006). The deterioration of the traditional system coupled with decreased land productivity is much aggravated by excessive tree cutting, and unfavorable socio-economic conditions (Barbier, 1992). Environmental changes and consecutive drought years, in addition to high population growth, land tenure problems and consequent recurring food shortages, render the practice of traditional farming system difficult. Hence, farmers were forced to develop certain mitigation strategies to overcome those adverse conditions and to sustain their farming system.

1.1. Problem Statement

The Sudan Central Bureau of Statistics, (2011) estimates the population of Sudan as 39 million (before cessation) growing at 2.7%, with more than 30 million people living in rural areas. Over 80% of Sudan‘s employment takes place in the agricultural sub-sector. Majority of the population are farmers and pastoralists living on subsistent farming and livestock herding in a transhumant way of life. Rainfall in some areas of the country has been steadily decreasing over the last 40 years, and the desert is advancing at a rate of about one mile a year at the expense of grazing land and water sources. Forest ecosystems have been degraded due to fire, uncontrolled grazing, overcutting, and encroachment by agriculture. Environmental degradation and competition for limited natural resources have contributed to conflicts in the region (UNEP 2007). Increasing population versus diminishing natural resources have aggravated the problem and enhanced soil erosion, loss of soil fertility, deforestation, loss of vegetation cover and drop in ground water table. Regarding community livelihood dimensions, the situation exhibits itself in low standards of living in rural areas and high rates of unemployment among villagers who have been enforced to either develop some mitigation strategies to overcome these adverse effects or migrate to urban areas.

1.2. Objectives

The overall objective of this study was to enrich scientific data and contribute to research documentation in the field of indigenous knowledge through highlighting the strategic approaches followed by farmers to mitigate the impact of climate variability and unfavorable environmental conditions. However the specific objectives were:

- To identify and characterize mitigation strategies adopted by local communities.
- To assess and scrutinize the effect of those strategies in improving the farming system.
- To assess the political ecology approach as a mean for tackling population-environment relations.

2. Methodology

The study area, Um Eshera Administrative Unit, is located in North Kordofan State, a semi arid area in mid-west Sudan, lies within the savannah zone between latitudes 9º 5' and 11º 7' N and longitudes 27º and 32º E. It is the main producing area of gum arabic, and it spouses the largest gum arabic market in the world in its capital Elobeid. Administratively, the state is divided into 9 localities (Figure 1), comprising 33 administrative units. The population is 3,200,000 (Population Census 2008). Social survey using a structured questionnaire and political ecology approaches were the main tools used for data collection. Stratified random sampling technique was used targeted 8 villages in the area, and the household represented the basic unit of analysis.

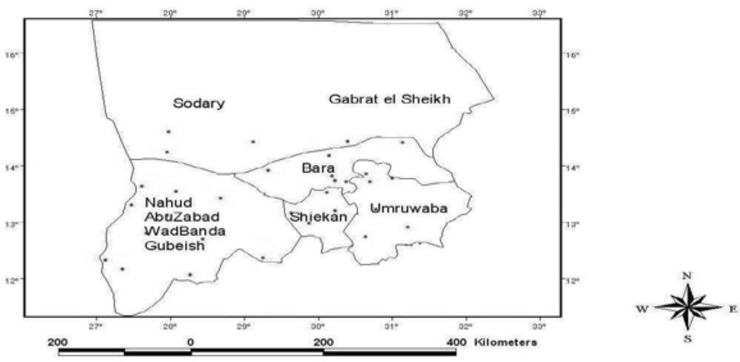

Figure 1: Localities in North Kordofan State

Two strata were determined where villages were divided into small and large size villages. From each stratum, a random sample representing 5% of the total household's number was taken. Sample size was 92 farmers. Direct observations and informal interviews with farmers were other important sources of primary data. Secondary data used relevant reports and previous researches in the same field and literature related to research themes were used. SPSS software was used for data analysis, using descriptive statistics and chi squire test.

Literature Review: Agriculture is the main form of livelihood in the study area. Farming system is basically subsistence production based on shifting cultivation and livestock rearing. This sector is characterized by low productivity. The extreme rainfall variability (Figure 2) has made traditional farmers highly vulnerable to drought, while the extensive farming and slash and burn practices pose serious environmental threats. These coupled with unregulated expansion has played destruction to the country's environmental resources resulting in extensive removal of trees, land degradation and destruction of habitats.

The well known and acknowledged farming system, which involves the Acacia tree, was disrupted posing negative environmental and socio-economic impacts on the gum belt where the study area is located.

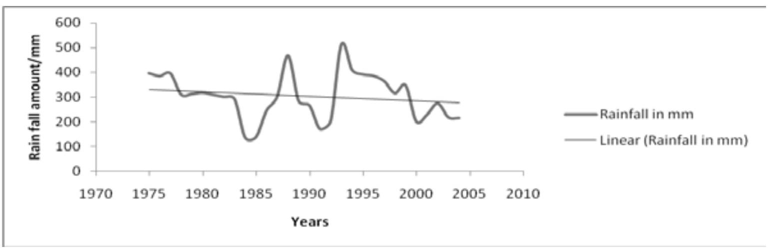

Figure 2: Time series data of rainfall in Um Eshera Administrative Unit

Gum Arabic, produced from *Acacia senegal* tree, is an important off-farm activity for more than five million people or 13% of Sudan's population. In addition to producers hiring entire families living in the gum belt for four months in the dry season, when labors migrate to areas for temporary employment. 19% of household earnings come from activities related to gum Arabic. It is a critical source of income in rural areas where opportunities are limited and where the workforce is often not mobile or able to engage.

The common natural resources management systems act to assure access to important natural resources by all members of the community including the landless and other marginalized groups. They fulfill important social functions such as maintaining conflict resolution mechanisms and can also assure conservation of natural resources and biodiversity.

Why political ecology approach?

Political ecology may be defined as the attempt to understand the political sources, conditions and ramifications of environmental change Blaikie and Brookfield, (1987) Such a definition has much to commend it, particularly when extended to encompass not only 'land', but more generally 'environment'. It is therefore important to review briefly the ways in which economic reductionism simplifies reality, diminishing analytical accuracy, as Blaikie (1989a) notes in the context of African desertification:

In addressing the political ramifications of environmental change, however, caution must be exercised. Analyses of how environmental change may affect diverse socio-economic groups and concrete political processes differ, and must never be confused with environmental determinism. Discussion of the political ramifications of environmental change is designed to complement understanding of the other elements of the framework-the contextual sources of environmental change. political ecology has nevertheless until recently contained 'very little politics'; meaning there was no serious treatment of the means of resource control and access, nor of their definition, negotiation and contestation within political arenas (Peet & Watts, 1996).

A political ecology approach also requires engagement of resource scarcity. According to advocates of the scarce resource wars hypothesis, people or nations will fight each other to secure access to the resources necessary for their survival: the more scarce the resource, the more bitter the fight (Homer-Dixon, 1999; Suliman, 1998 , Dalby, 1998; Peluso & Watts, 2001). This situation is typical to the study area, but due to the tribal homogeneity and rationale tribal leader system, resource scarcity has let to mitigation strategies rather than conflicts. This pioneer loom needs empowerment, research intervention and replication in other areas of similar conditions.

3. Results and Discussion

Demographically, study results showed that the majority of the population belongs to Showaihat tribe, which constitute 64%, next comes the Bedairiya 21%, the rest are different tribes. Tribal composition is very important in rural areas as it is the determinant for land ownership. Study results showed that 48% of respondents have their own lands while 40% have rented lands. Age group less than 15year was represented by 49%, while 15-45 year was found to be 40%, whereas more that 45 year age was represented by 11% this result indicated that village out migration is obvious, the majority of people was less than 15 years (below employment age). Illiteracy is found among 44% of the respondents, illiteracy is a real threat to development so enhancing education level of local communities is the top priority need for any future community development project or activity. Improving education level and developing peasant skills and levels will reduce the risk of conflict over limited and diminishing resources, this goes on the same line of the finding of (Ranis, 1987), who mentioned that, it is in the interest of the elite of resource poor countries to develop and harness human capital, rather than protect scarce or non-existent resource rents. In this view, the likelihood of violent conflict decreases as human capital develops through education, trading and manufacturing skills. Regarding factors causing environmental degradation, the respondents reported that rainfall deficiency is the most significant factors affecting the environmental conservation. Grazing does not have much harmful impact on natural regeneration. This view was confirmed by field observations, that there was no considerable amount of livestock inside the village forests therefore the natural regeneration appears to be acceptable.

Among the mitigation strategies adopted by farmers as study result showed was to leave part of the land uncultivated. This was mentioned by 51% of farmers. Farmers' point of view is that many reasons are behind abandonment of some farm areas these are namely lack of financial support, low rainfall, low crop productivity, low prices in addition to other reasons such as pests, labor shortage and high labor cost. All those reasons are summarized in Figure 3.

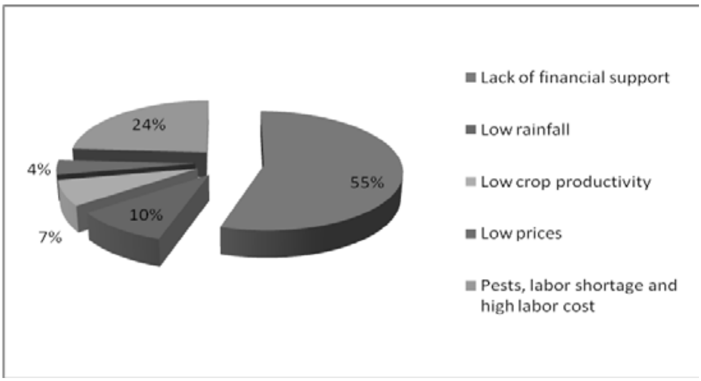

Figure 3: Reasons behind leaving some areas without cropping

To overcome adverse condition and to contribute to food security study findings showed that farmers were concentrating on food crops, though crop types depend on rainfall and soil type, regardless of the total area needed to be cultivated and then comes cash crops, therefore 88% of respondents cropped sorghum while 12% cropped sesame, crop combination is an obvious farming practice in most cases. Whatever crop type were harvested, farmers tried to optimize the utilization of their produce as indicated in Figure 4.

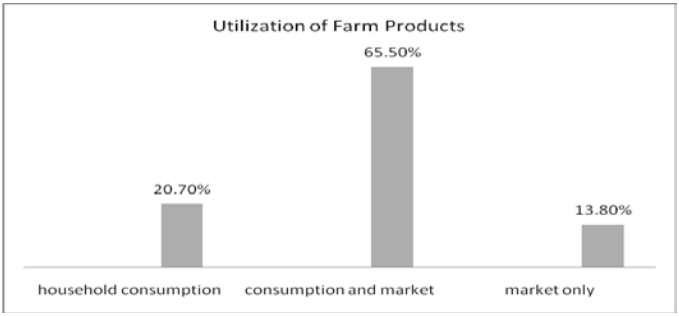

Figure 4: Utilization of Farm products at Um Eshaira, North Kordofan

Study finding showed that there were still some adverse farming practices such as that all farmers burn their farms after collecting their harvest but at different time, 53% burn before rainfall, 44% burn after harvest, while 3% after rainfall. Regardless of burning time, the activity of burning accelerate drought by reducing vegetation cover, leading to sand dune mobility and loss of soil fertility. Other adverse practice is tree cutting during weeding activity, 52% of farmers mentioned that they cut trees as they are habitat for birds, so by cutting trees birds will not settle in their farm so farmers believe that they can reduce the risk of bird epidemics. It is concluded that removal of trees under such adverse climatic condition will hinder the land productivity and in the long run would lead to collapse of the farming system. Study results also revealed that some mitigation strategies were developed by farmers to sustain the farming system under the prevailing environmental and climatic inconveniences, the most important strategies were, dry sowing "Ramil" which was practiced by 97% of farmers, it is the activity of seeding before rain starts. People believe that this strategy is the most effective one because it has many advantages summarized in Figure 5.

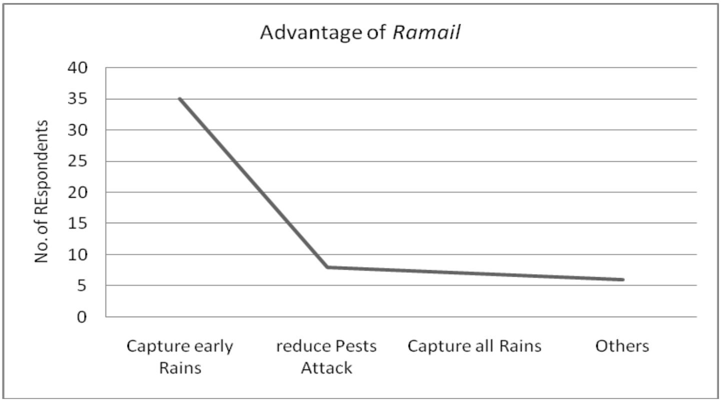

Figure 5: Advantage of Ramil as a Mitigation Strategy at Um Eshaira, North Kordofan

People also rely on cultural knowledge to divide rainy season into sub-seasons known locally as Eina which is 12 days, each Eina has certain amount of rainfall. Farmers depend upon their own prediction and decide on each activity to be made According to specific characters of the period. Table 1 showed different type of Eina as mentioned by the respondents.

Table 1: Indigenous Classification of the Rainy Season

Name of Eina	Duration	Characters of the period
Doraa	7-19 June	Summer time
Natra	20July-1 August	Onset of rains
Tarfa	2-14 August	Heavy rains
Gabha	15-27 August	Heavy rains
Khorsan	28 August-10 Sep.	Low rains
Sarf	11-23 September	Time of Insects and pests
Awaa	24 Sep.-6 October	Rains spoil the harvest
Samak	7-19 October	Late rains

Source: Field survey 2007

Other mitigation strategy is the use of improved variety seeds, 79% of the respondents mentioned that they used improved variety seeds selected during the harvest period. Some farmers provide improved seeds from the ministry of agriculture while the rest provide the seeds from the market. Using the chi squire test (significant at 0.5

level) shows that use of improved variety seeds has significantly increase farm productivity. Other mitigation strategies were intercropping, fallowing, increasing seed rate to avoid risk, cropping near water courses and rain capturing through planting in different direction in addition to other practices that people believes they help them harvest their crop needs. Study results showed that local people have adopted some non-farm mitigation strategies to overcome the risk of harvest failure or to secure their harvest for household consumption. These are summarized in Figure 6, other non-farm related adaptation method mentioned by respondents was selling their properties (if there are any).

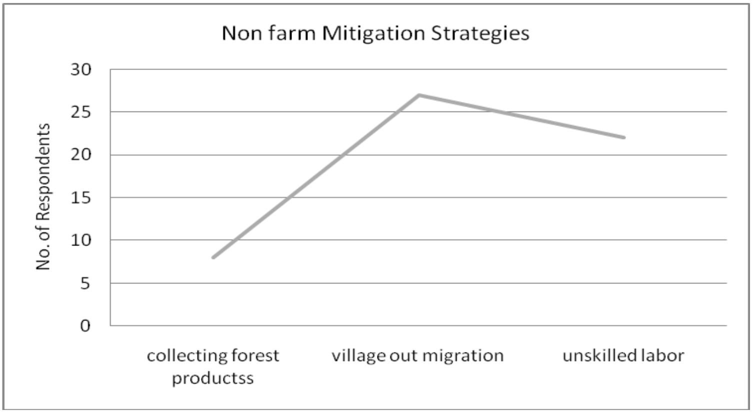

Figure 6: Some Non-Farm Mitigation Strategies at Um Eshaira, North Kordofan

It is clear from figure that due to absence of development institutions and job creation opportunities in the area, weak knowledge and absence of technical skills for farmers, the latter found it difficult to be involved in income generating activities. The majority of them migrated outside the village to do marginal jobs as unskilled labor. The result of chi squire test (p=0.5) revealed that those mitigation strategies were significantly contributed to secure crop productivity and help in people's settlement. It is concluded that some adverse farming practices such as removal of trees under adverse climatic condition will hinder land productivity and in the long run would lead to collapse of the farming system. The study recommended that local knowledge and indigenous mitigation strategies have to be furnished with intensive extension packages of environmental services of trees, agroforestry and land use saving to contribute positively to land rehabilitation and soil degradation problems. It is also recommended that the forgoing strategies could be incorporated in the curricula of natural resources institutions so as to formulate a real contextualization of learning resources.

References

Badri, S. (2012) Sudan Environmental Threats and Opportunities Assessment with special focus on Biological Diversity and Tropical Forest, Washington, DC20024, USA.

Ballal, M.E., El Siddig, E. A., Elfadl, M.A. and Luukkanen, O. (2005) Relationship Between Environmental Factors, Tapping Dates, Tapping Intensity and Gum Arabic Yield of an Acacia senegal Plantation in western Sudan, *Journal of Arid Environments* 63.

Barbier, E.B. (1992) Rehabilitating Gum Arabic Systems in Sudan. Economic and Environmental Implications. *Environmental and Resource economics*, 341-358.

Blaikie, P. (1989) Environment and access to resources in Africa. *Africa* 59, 18-40.

Blaikie, P. and Brookfield, H. (1987) Land degradation and society.

Cossalter, C. (1991) Quick Guide to Useful Nitrogen Fixing Trees from Around the World; Acacia senegal, Gum Tree with Promise for Agroforestry, NFT highlights, NFTA 91.

Dalby, S. (1998) Ecological metaphors of security: world politics in the biosphere. *Alternatives* 23, 291–319.

El Samani, M.O. (1986) Kordofan Rehabilitation Development Strategy, Vol. 1, main report, Institute of Environmental Studies (IES), University of Khartoum and the Government of Kordofan Region.

Homer-Dixon, T. (1999) Environment, scarcity and violence. Princeton, Princeton University Press. Methuen and Co. Ltd.

Peet, R. and Watts, M. (1996) Liberation ecologies: environment, development, and social movements. London. Routledge.

Peluso, N.L. and Watts, M. (2001) Violent environments. Ithaca, Cornell University Press.

Raddad, E.Y. (2006) Tropical Dry land Agroforestry on Clay Soils: Analysis of systems based on Acacia senegal in the Blue Nile region, Sudan, Academic dissertation, Faculty of Agriculture and Forestry of the University of Helsinki .

Ranis, G. (1987) Towards a model of development for the natural resources poor economy. Discussion Paper 529, Yale Economic Growth Center, Yale University, Yale.

Suliman, M. (1998) Ecology, politics and violent conflicts. London, Zed Books.

United Nations Environment Program (UNEP) (2007) Post-conflict Environmental Assessment in Sudan.

Climate Variability and Change: Implications for Household Food Security in North Kordofan State

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Abstract

This study assesses the potential economic impact of climate variability and change and socio-economic characteristics that hinders the household food security, in order to provide a meaningful insight and contribute to efforts aimed at ensuring increased food availability through sustainable domestic production and increased income from agricultural production. In Sudan general and North Kordofan State in particularly many researches and studies has been carried out in the area of household food security. Most of these studies have been indicative and either descriptive or have tended to limit themselves to the national level. The data on having national food balance is not sufficient to understand the food security dynamics in the country and no clear definition of food security and categorization at the farm household level.

The study was conducted on the basis of cross-district analysis and extrapolates the results to all localities in North Kordofan State, Sudan. One hundred households were randomly selected for interview using pre-constructed questionnaire during 2011-2012 season. The study identifies choice for adaptation measure that farmers are using to mitigate potential environmental impacts from expected variables in climate change conditions.

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The study utilized the statistical descriptive and an econometric techniques to describe the trend of impacts of climate variability and change and socio-economic characteristics on food security in North Kordofan State. The results indicated that the climate variability and change and socio-economic are the important factors that affecting the production and productivity of crops in traditional rain-fed sector and household food security in the region.
The results of the household food security indicator which calculate from Gini coefficient, descriptive and econometric model showed that the production fluctuated due to many factors such as seeds, area cultivated, and type of land, costs of production, rainfall distribution, and farm and off farm income, animal ownership and educational level. In General results show that 75% of households did not have sufficient food secure their needs, whereas 73% of households reported inadequate income to buy food. It should, however, be noted that the food quantities reported by most households interviewed in the study area are considered to be inadequate and very low as indicators to characterize the household food secure and household food insecure at the household level.

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1. Introduction

Sudan is a low-income country, with income per capita of less than US$ 400, with its vast geographic area and varied natural resources, it holds great economic potential. So far, however, it has been a land of missed opportunity (Medani etal 2006). Yet, it faces many challenges after missing the oil resource due to the separation of southern Sudan to utilize these diversified resources to attain mitigation of poverty (Abaker and Salih, 2011). Despite that and since 1970s, the country economic growth has been associated with increasing in poverty. The situation has been aggravated by liberalization policies during 1990s which has affected both growth and income distribution (World Bank, 2003).

The traditional rain-fed sub-sector is considered as one of the most important components of the agricultural sector in the Sudan. However, it experienced sever episodes of droughts in the last three decades of the 20th century. Agriculture in North Kordofan State is integral part of traditional farming, before three decades productivity was high and household used to cover all grain or cereal needs from farm production i.e. through direct access. Over the years crop production has fluctuated due to many factors such as low/erratic rainfall, pest infestation and low soil fertility. The area has experienced high environmental degradations; resulted in declined productivity and depletion of large livestock herds along with plant species which makes most of the rural people living in highly vulnerable conditions. Accordingly, the area continuously experienced food gaps or food insecurity and getting food aids.

This study was undertaken to assess the impact of climate variability and change and socio-economic characteristics on household food security of rural farm household with emphasis on North Kordofan State. More specifically, to investigate the crucial factors regarding the decline in field crops as main sources of food security in the area as well as assess the impact of climate variability and change on livestock as second most important sources of food security in North Kordofan State.

2. Methodology

2.1. Study area

North Kordofan State is located in the middle west of the Sudan, lies in the arid and semi arid zones between latitudes 16°36 -16° north and 14°-12° south and longitudes 20° 21 - 32° east and 30° 56- 26° west. It encompasses an area of 244.700 km2 with total human population estimates based on the last census 2009, of around 2,920,992 persons most of which (80%) are allocated in the rural areas and the rest (20%) in the urban areas (CBS, 2010).

North Kordofan State was selected as a case of the study area for two reasons: First: it can be classified as one of the vulnerable and poorest State in the Sudan, as it is a frequent drought and desertification vulnerable area. Second: no many studies have been done and only few are known about the household food security in the State. This study concentrates on the impact of climate variability and change on household food security in North Kordofan State. Four essential factors determine the significance of agricultural production in North Kordofan State in relation to household food security. These include:

1) The number of household involved in crop production.

2) Types of crops grown.

3) Area cultivated by each crops.

4) Quantity produced from each crops.

The study used both primary and secondary data. The primary data were collected through direct interviews focused on the heterogeneity of the farmer's household heads using a questionnaire. A multi-stage stratified random sample method was implemented, and accordingly a number of 100 households were randomly selected during 2011-2012 cropping season. While, the secondary data were collected from published and unpublished sources, which included records, books, periodical reports and journals from relevant institutes.

2.2. Specification of Food Security Indicators

Consumption of cereals food: the household food security indicator was specified as a measure of cereals food consumption. Conceptually, the amount of food needed by an individual is dependent upon several factors including: age, sex, type of work he/she does and the prevailing climatic condition. This study, used the recommended daily amount of cereals requirements by the FAO, AOAD and WHO, which set the average food needs at about 400 grams of cereal crops per person per day or (140 -146kg/years per person), as indicators to characterize the household food secure and household food insecure at the household level for different categories of household members. Considering the specific features in developing countries the WHO (1985) and CARE (1997) were utilized general formula as follow:

Where:

X = Amount of cereals food required per household members per year.

P = Food consumed by the age

Q = Food consumed by the sex

S = Total food consumed by the household size

360 = Number of days in the year.

However, in much of African countries, Asia and Latin America, the average intake is 400 gram of cereals or 2100 kilo calories per person per day (Fyson, 1972).

Gini coefficient: is a measure of income inequality. Gini coefficient is a number between 0 and 1, where 0 corresponds with perfect equality (where everyone has the same income) and 1 corresponds with perfect inequality (where one person has all the income, and everyone else has zero income).

The Gini Index is calculated as follow:

$G = 1+1/n-2/n2M \Sigma \Phi i\ Yi$

Where:

G = Gini Coefficient.

n = number of sample households

Φi = ith rank of the household when arranged in a descending order with respect to income

Yi = income of the household in the corresponding ith rank

M = sample mean income.

2.3. The Econometric model

Constructing an econometric method to identify the relationship a set of variables and the farm household expenditure will use OLS estimation. The technique based on the principle of minimizing the sum of squared residuals has the desirable properly of mathematical objectively .The criterion of OLS provides estimates that possess many useful and desirable properties (Chandan et al, 1998).

2.3.1. Regression model

$Y= ß_0+ ß_1x_1+ ß_2x_2+... + ß_mx_m +e_i$

Where:

Y = output (dependent variable)

$ß_0$, $ß_1$, $ß_2$... $ß_m$ are the parameters.

e_i = random variabile = (error).

x_1, x_2, x_m = are Independent variables.

2.3.2. Regression Equation

$E (y) = ß_0+ ß_1x_1+ ß_2x_2+......+ ß_mx_m$

$\hat{Y} = b_0+b_1x_1+b_2x_2...+b_m x_m$

Where:

$\hat{Y}$ = Estimated value of dependent variable

$b_1, b_2 \ldots . b_m$ = are the estimates of $ß_0, ß_1, ß_2 \ldots ß_p$.

$x_1, x_2, x_3 \ldots x_m$= independent variables.

3. Results and Discussion

Cereal crops such as millet and sorghum are the main staple food crops widely grown in North Kordofan State. For example, 88% of households in North Kordofan cultivate millet. Furthermore, 74% of households in North Kordofan also grow sorghum. In recent times sorghum is usually cultivated to serve the household consumption needs since millet has declined in productivity especially in North Kordofan.

Cash crops such as groundnut and sesame are important to the household economy. For example more than 48% of households grow groundnut in surveyed sample whiles 58% grow sesame, in addition to other minor crops grown at home gardens like rosella, cucumber, okra, cowpea and other vegetables. For these crops, women and children do all farm operations and women afterwards mostly control benefits, though they are done in the interest of the whole household. The extent of food and cash crop production varies from season to season.

This section captures some of the factors that interact to characterize the food secure and insecure at the household's level based on some economic concepts. Farm household resources and assets represent the availability of productions means and the infrastructures needed in the region to enhance productivity.

The household income and sources of household basic supply; the cash income gives the purchasing power for securing household goods, which also contributes to household supply of which food is the most critical. Some gift and remittances received by farm the households could either be in cash or kind, both of which contribute to household supply.

Household income consists of farm income as mean 146156.0SDG and Std. 173343.7SDG, and off farm income and remittances. Off farm income (95541.1Sd as average and Std. 102893.5) includes income from all economic activities outside the farm work. Various uses of household income could be in form of cash or kind. The cash uses include living expenses of household including health expenses, education expenses, social obligations and others, expenses back into the farming in subsequent seasons. The uses in kind could either be direct home consumption from subsistence production and/or payment of wages in kind. There are different pathways to measuring food security at the household level. Some measures are used directly to assess food security while others are used as proxy variable. This study investigates whether an average rural farm family has both physical and economic access to enough food for all household members, and the consequential impact of their availability, accessibility, affordability of food, on food security.

Access to Food and Food Consumption in most rural areas there are three ways of obtaining food: production, purchase and transfer.

Consumption of both farm and non-farm products has changed over the years as an adjustment to the growing risk of food insecurity.

Households in the study area depend mainly on their own production in order to satisfy their basic food needs. Nearly all households produce at least millet and sorghum, as staple food for home consumption in north Kordofan state mainly millet. With exception of low-income area located mainly in traditional rain-fed sub-sector, most households reported that they did not were produce enough from staple food. It should, however, be noted that the food quantities reported by most households interviewed in the study area are considered to be inadequate and very low as indicators to characterize the household food secure and household food insecure at the household level.

Table 1: Households cereals Consumption in Grams and Equivalent Units Approved by: WHO, CARE, OADA and FAO.

North Kordofan % Of HH	Consumption (Cereals) in grams
29	400 >
36	600-400
24	800-601
8	1000-801
3	1000 <
100	Total

Source: Field Survey, 2011.

If these criteria are applied, only 70%of the interviewed households reported self-sufficient in north Kordofan at least in producing the main staple food crops (millet and sorghum) for home consumption. This may be explained as follow: Firstly, households generally refuse to discuss food problems with others as they feel ashamed and deny that they run out of food at certain periods of the year. Secondly, although some household may store only little millet, they may be in fact self-sufficient as they can depend on reserve crops such as, sorghum when millet stocks are depleted. In addition, they may consume other foods, which were not mentioned during the interview, e.g. wild food. About 45.5% of the interviewed household in the study area admitted to being unable to cover their food needs via home production, because food stocks do not last for more than three or four months. This differs, however, from household to household and from village to village in North Kordofan State.

Although the clear shift in the production structure from millet to sorghum as the staple food may have had an adverse effect on food security. The production of millet in North Kordofan State for home consumption may still contribute substantially to household food security; millet can be used as reserve crop it can be readily to store for a number of years.

In this study, Gini coefficient is calculated in order to measure income inequality among the rural households in North Kordofan State. In Gini coefficient, households are ranked from the lowest to highest according to their annual income. Gini coefficient of households in North Kordofan State based on total households farm income and off farm income were as fallow: Gini coefficient based on total farm income for all household in North Kordofan is 0.28725 based on annual farm income, indicating that farm income of households in North Kordofan is less equally distributed. While, the Gini coefficient based on off farm income for all households in North Kordofan is 0.19082, indicating that income earned from off farm jobs also is less equally distributed. This result explores the sources of income distributions among households in North Kordofan State in general. The general results revealed that annual household's farm income is distributed much more unequally among households than is annual households off farm income in North Kordofan State. Among different types of households in the study area, one household in each part of the localities of the State have the greatest inequality in the distribution of income and expenditure, whereas income and expenditure are most equally distributed among one household in the State.

3.1. Factors Affecting Total Household Expenditures Determination

The study aims to investigate the critical factors influencing household food security in North Kordofan State by using econometric model mainly matrix correlation and multiple regressions as a method of analysis. The relationship between dependent variable and independent variables was shown by the linear consumption function chosen as follows:

In this equation bellow, the dependent variable (Y) is total household expenditures in north Kordofan in SDG per year and continuous (predictors) variables are the "age of household, household size, total farm income, total off-farm income, and number of meals, and annual household consumption. In addition to these there are many dummy variables were used: household head, education level of household head, educate female, educate male, land ownership.

$Y = ß_0 + ß_1 HHhead + ß_2 HHage + ß_3\ HHsiz + ß_4 HHeduc + ß_5 Educm + ß_6 Educf + ß_7 Nomeals + ß_8 HHcons + ß_9\ Animal\ own + ß_{10} Fincome + ß_{11} OFFFinc + E_i$

Where:

Y = Total household expenditure (dependent variable).

$ß_0$ = the intercept.

HH Head = Vector of dummy variables indicating gender of household.

HH Age = Variables of household age

HH Size = Variables household size.

HH Educ. = Variables of education level of the household head.

Educ M = Variables of education level of male.

Educ F = Variables of education level of female head.

No Meals = Variables of number of meals.

HH Consumption= Variables of households annual consumption indicating quantities cereal crops of households consumption.

Animal Own = Dummy variables indicating household own animal. Farm Income = Variables of net farm income.

Off Farm Income = Dummy variables of off-farm income.

E = Standard Error.

$ß_1$, $ß_2 \ldots ß_{14}$ = are the coefficients (are parameters of explanatory variables).

3.2. Factors Affecting Total Household Expenditures Determination in North Kordofan

Table (2) shows the result of the estimated model in North Kordofan, Adjusted R-Squared 52.5%, which indicates could be explained by these variables 52.5% of the variance in the household expenditure in North Kordofan. F- Statistic was significant at 1% of significance.

Table 2: Total Household expenditure regression equation in north Kordofan

Variables	Coefficients	Standard errors	T-values
DUMMY-Household Head	0.026	19380	0.716
Age of household	-0.347*	666.3	-1.386
Household Size	0.187 ***	3200.4	3.264
Education level of HH	-0.240 *	14887.7	-1.451
DUMMY Educated male	-0.385	4051.2	-0.862
DUMMY Educated female	-0.370 **	4432.7	-1.945
Number of meals	0.307	14360.8	1.267
Household consumption of cereals	0.411	25088.4	1.110
NUMMBER OF owned Animal	-0.050***	17537.0	-3.717
Net farm income (SD)	-0.141 ***	0.018	-4.942
Off-farm income	-0.451 ***	14083.8	-6.896
Constant	53723.3 ***	5822.2	2.642

Source: Field Survey, 2011

F-value=16.325 (.000) $R_2 = 0.625$. Adjusted $R_2 = 0.525$ Standard error = 44521.87583

, ** And * denotes significance at 10%, 5% and 1% levels respectively.*

North Kordofan localities are similar in traditional method of production and culture is thus characterized by seasonal or transitory food insecurity and rarely chronic food insecurity of household in all areas. Moreover, households in North Kordofan State hardly to cover their needs via home production and food stocks do not last for more than three or four months. In season 2011-2012, 29% of household in North Kordofan were food insecure according to the standard criteria applied by FAO, CARE, WHO and AOAD, while, this percentage is high level of food insecurity would even be worse in marginal parts of the State with less favour in resources endowment, mainly in the northern and western parts of the North Kordofan. Most of households in North Kordofan, produced (90 %) are sold. These include cash crops such as groundnut, sesame and rosella and others.

Millet and sorghum are also utilized in home consumption. Generally, however, households in rural area fail to use their production resources for diversifying their production to ensuring a balanced diet from their own farming operations.

Four equations of Millet, Sorghum, Groundnut and Sesame were estimated. The regression equation coefficients and statistics for the four crops are presented in table 3.

Table 3: Regression Coefficients and Statistics for the Production Functions of the Major Field Crops in North Kordofan State

Variable	Millet	Sorghum	Groundnut	Sesame
Household size	-0.098	0.087	-0.008	-0.306
	(-0.793)	(0.874)	(-0.049)	(-2.516)
Quantity of seeds	-1.359***	-1.085*	-0.420*	000
	(-3.385)	(-1.827)	(-1.603)	(000)
Areas planted	1.455**	1.101*	0.797**	0.593
	(3.765)	(1.917)	(2.934)	(0.585)
Type of land	0.694***	0.778***	-0.585**	0.270**
	(6.268)	(7.210)	(-3.275)	(1.508)
Cost of production (SD)	-0.381	0.034	0.118	000
	(-2.737)	(0.292)	(0.731)	(000)
Net farm income (SD)	0.221*	0.231	-0.252	-0.090*
	(1.901)	(2.405)	(-1.631)	(-0.550)
Off-farm income	-0.007	-0.100*	-0.349*	0.492
	(-0.056)	(-1.039)	(-2.280)	(4.319)
Animal ownership	0.481**	0.136	000	0.197*
	(3.671)	(1.457)	(000)	(1.338)
Rate of rainfall	0.254**	-0.285*	0.537**	-0.745**
	(1.954)	(-2.661)	(3.156)	(-6.552)
Constant	-.534**	-.199**	3.078**	0.836*
	(-1.939)	(-3.619)	(3.961)	(2.497)
R –squared	0.736	0.680	0.722	0.673
F –value	6.596	8.712	4.223	5.575

Source: Calculated from field survey, season 2011/2012.

, ** and * denotes significance at 10%, 5% and 1% levels respectively.*

As shown in table (3) from the variables included in the equations of production function the significant independent variables were: age of household, household size, quantity of seeds, area cultivated, and type of land, net farm income, off farm income, animal ownership, and rate of rainfall.

The explanatory powers of the equations were very high, as coefficient of determination (R2) for the regression equations were 62.5%, 60.5%, 55.1% and 55.2% for millet, sorghum, groundnut and sesame in north Kordofan, respectively. Moreover, the F-test of each equation indicates its overall significance at 5%. However, these differences in the productivity in North Kordofan State between crops

Household farmers in North Kordofan State are free to select their size farm; they fallow a prescribed rainy season. In this regard, (Mukhtar and Elfadni, 2004) reported that variations in the productivity of crops in North Kordofan State coupled with poor sandy soils; high variability of rainfall between years and within a year, and land misused had upset ecological balance and socio-economic problems. Most importantly is declining crops productivity, especially on sandy soils, which occupy 60% of the State. These results may tend to support the common assumption of high shortages of food in western Sudan, some people still rely on food assistance because of the lingering effects of last decades droughts, coupled with tribal conflict in some parts of the State.

This shows that the households attempt to balance between food and cash crops production. Moreover these trends of household in the cropping pattern in the traditional rain-fed sector point out the relative high production risk and as a result the household inclination to go through different ways to risk management strategies, which are required to cope with the expected relatively high probability of crop failure. Productivity of crops depends on several factors including land type, rainfall distribution (starting and ending), early planting, weeding, moisture distribution and pest and farm management practice. The average household produce is very low of all cereal crops. However, low yields of different crops in surveyed area could be attributed to that household tend to fallow a monocropping pattern; inorganic fertilizer was not applied for various season. Also, agriculture is practiced on low rainfall agro-climatic zones that experience below 300mm of rainfall. All of these factors led to low yields.

4. Conclusion

This study tries to fill the existing research gap in the literature by examining the impact of climate variability and change and socio-economic on farming activities in dry land agriculture. The empirical results implied that the test of the efficiency of high food security and inequality among farmers is due to many economical, social and environmental factors in North Kordofan State do not behave as predicted by the production function analysis; among which the recent neglect of the government to traditional rain-fed subsector is the main factor that make agriculture performing below its potential in recent years. The unstable weather conditions led the majority of farmers depend on fluctuated rainfall for crop cultivation. In fact, agriculture can contribute to rural household food security and poverty reduction three times or more than any other sectors do. Thus combating overall farmer food security in general and poverty in particular, requires policy interventions that consider the variation among farmers for eliminating the existing inequalities and boost farm output.

However, this result may be taken with caution given the fact that in reality many existing conditions support the factors of production behavior.

References

Abaker, A.C., Ali Musa and Salih, Ali Abd Elaziz (2011) Poverty and inequality in industrial sector of Sudan. Research Paper. Scholarly Journal of Business Administration 1(4), 83-88.

CBS, (2010) Central Bureau of Statistical, Khartoum, Sudan.

Chandan, M.H. and Marc, W. (1998) Econometric and Data Analysis for Developing Countries. London and New York.

Elamin, E.M. (1998) Towards Understanding the Behavior of Small Producers Facing Additional Risk of Cash- Oriented Agricultural Policy. The case of Dry-land Farming in Western Sudan. Agricultural Research Journal, Wad- Madani, Sudan 1.

FAO (1983) Approaches to World Food Security-Selected Working Papers of the Commodities and Trade Division. FAO Economic and Social Development Paper, No. 2, Rome.

FAO/WFP (2004) FAO Global Information and Early Warning System on Food and Agriculture, World Food Program, Special Report.

Fyson, N. (1972) World Food B.T. Batts Ltd, London.

Medani et al., (2006) Macroeconomic Policies for Poverty Reduction: The Case of Sudan.UNDP-SUDAN.

Mukhtar, M., Bashir, A.E. and O. Elfadni, (2004) Plans of Action for the affected Kordofan States by Drought. Elobeid Agric. Research Station, North Kordofan, Sudan.

World Bank, (2003) World Development Indicators 2003. Sudan, Health Status Report/AFTH3. Washington, D.C. CD ROM.

Land Deterioration in Relation to Climate Change: Features, Consequences and Remedies with Emphasis to the African Case

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Abstract

This document is a review synthesized from published material that deals with effects of climate change on land degradation. It is evident that changes in land conditions are linked to the climate change by definition. The concern is, however, focused on the recent impacts of devastating climatic conditions on land/soil state and properties in the view point of land use and utility perspectives. Worries on the subject matter are also stressed with respect to increasing population, land hunger and food production. The prominent features of climate change impacts on land degradation are exemplified in the loss of arable land or deterioration of its physical, chemical and biological properties. The phenomenon is widely spread all over the world and Africa is one of the continents that is hard hit by land degradation features. The consequences of land degradation are multiple and variable in degree and extent and can vary from affection of livelihood to violent conflicts and mass displacement of people. As the problem may virtually affect every one on the planet earth, so the first steps to dealing with the matter is to arise public awareness and educate the future generations. It exist many procedures and technologies to dealing with the issue of land degradation problems; perhaps what is lacking is the national sensitivity, particularly in the developing countries and more international solidarity to face the matter. Finally, it seems that

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mitigating the climate change impacts will constitute a major and continuous occupation for the human being in the future.

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1. Introduction

Land-soil degradation is a continuous process occurring even in relatively stable climatic conditions. In effect, soils are formed, developed and degraded principally by the action of the climatic factors on the parent material, and with involvement of other factors like topography, vegetation and time. All the climatic factors (precipitation, temperature, wind, radiation, natural energy flows) are involved in the process of parent material weathering and genesis of soils. It is evident that the climate is simultaneously considered as soil formation and degradation factor. The land-soil degradation is also aggravated and accelerated by irrational and inappropriate anthropogenic activities. The driving causes, in this context are of socio-economic order (over population, land tenure, poverty, illiteracy, disorganization and mismanagement) and lack of adequate technologies, particularly in the developing countries. Thus, the human mismanagement and irrational land use coupled with the changing climatic conditions can lead to destruction of the natural resources through agriculture (mechanized and subsistent shifting cultivation), deforestation, over grazing, fires, oil exploration and mining…etc. The worry is not therefore from the simple fact that soils change due to climate change, but rather from the magnitude, the pace and the consequences of land-soil characteristics alteration ensuing from the recent climate change phenomenon. The alteration of land-soil properties are thus multiple and of variable nature, they can include, physical, chemical and biological characteristics (Oldeman 1992; Stocking and Murnaghan 2000; Eswaran *et al*. 2001; WMO 2005; Allen *et al*. 2011; Godone and Stanchi 2012). It is worth to mention that not all the changes in land–soil properties are harmful, but some may be beneficial, even though people are inclined to concentrate on the deleterious effects for evident reasons. The consequences of land degradation are diverse and of variable amplitude (Reich *et al*. 2001; MEA 2005; Reuveny 2007; Hendrix and Glaser 2007; Raleigh and Urdal 2007; Obalum *et al*. 2012). The capability of degraded land is seriously reduced or lost so that its usual utilization is jeopardized and can no longer afford to render the expected production levels, be it agricultural, pasture and livestock or forestry out puts. These in turn can cause loss of jobs, income and deterioration of people's livelihood. In such situations, people are compelled to reduce their living standards, displace, become vulnerable to catastrophes and diseases, face violent conflicts…etc. At the front line of the remedial procedures for land degradation problems is that people have to abide firmly with the land conservation measures and to exploit judiciously the land resources. Rehabilitation and restoration of land degradation measures are also variable and vast in nature and degree. They can range from simple hand-hoe manipulations to sophisticated mega-engineering works on landscapes (Stanley 2011). Recourse to appropriate technologies can facilitate to overcome problems of land degradation to a great deal; for example in agriculture: selection of resistant and highly productive germ plasm; efficient irrigation methods; adoption of appropriate crop rotations…etc (Scherr and Yadav 1996; Buresh *et al*. 1997; Reich *et al*. 2001; SWCS 2003; Blay *et al*. 2004; Gisladttir and Stocking 2005; Swift and Shepherd 2007; Brown *et al*. 2010; Brunn 2011; Chidumayo *et al*. 2011; Lipper *et al*. 2011; Turral *et al*. 2011). Education, extension and raising awareness, both for the specific land users and the public at large would help very much to conserve and attenuate the deleterious consequences of land degradation.

The aim of this article was to assemble a reviewing assessment from the recent documentation on the subject of land degradation as triggered by the climate, its extent, consequences and remedies with emphasis on Africa.

2. Land Degradation Causes and Features

The terms land and soils ought to be distinctly defined from each other (land expresses the horizontal stretch of the earth surface, whether soils express rather the vertical face of the earth), yet they are intimately related so that in many cases they are used invariably. There is also no consensus in defining the terms land/soil degradation and their assessing methods for many reasons including the diversity of the subject globally and its perpetual occurring nature even in the "normal" climatic conditions (Oldeman 1992; FAO 1997; Eswaran *et al*. 2001; FAO 2002; WMO 2005; Allen *et al*. 2011; Godone and Stanchi 2012). However, many authors agree to regroup the land/soil degradation into three categories: physical, chemical and biological features (Oldeman 1992; FAO 1997; FAO 2002; SWCS 2003). Physical features of soil degradation can include: decapitation and mass movement of soil and land deformation, sedimentation, alluvium, loess, colluvium, degradation of soil texture and structure, compaction, sealing, crusting, desiccation, rising of ground water table and creation of hydromorphic conditions. The chemical degradation can exhibit the following features: leaching, lixiviation, loss of nutrients or organic matter, salinisation/alkalinization, acidification, pollution/contamination. Mean while the biological deterioration may be evidenced by: organic carbon and organic matter depletion, disturbance and death of beneficial soil biota and eutrophication.

Land/soil degradation causes either are of natural origin or induced by anthropogenic activities. The recent anomalies of changes in climatic conditions are usually considered to be triggering reasons for land degradation; water and wind erosions are the major expressions in this respect. Violent storms and floods can engender complete loss of top soil, particularly in accentuated sloppy areas; and wind tempests are known to sweep land surface and move considerable amounts of soil (Zachar 1982; FAO 1997; Morgan 2005; Breuning-

Madsen and Awadzi 2005; WMO 2005; Prospero and Lamb 2007). Action of water runoff on the soil surface causes earth detachment and movement leading to creation of rills, gullies and surface deformations. Deep-water infiltration into the soil leads to leaching of solid particles and solutes; in areas of volcanic ash or calcium carbonate deposits, water percolation may cause formation of deep grooves into the soil (Zachar 1982; Arnalds *et al*. 2007). Prolonged droughts can cause soil desiccation, warming and detaching, which in turn increase its erodability. Soil chemical degradations (nutrient leaching (lixiviation), acidification, salinization, alkalinization..etc) may be brought about by more gentile water movements (water infiltration or capillary ascension) in the soils. In other cases soils may be submerged by surface water accumulation or raising water-table and thereby anaerobic conditions are created and with consequences of noxious reduction and acidification properties. Wind erosion is expressed by processes of dust launching, surface sweeping, encroachment, sand-dune creeping and resulting in soil compaction, sealing, encrusting, and terrain deformation and over-blowing. The soil material moved by the water (sediment, alluvium and organic debris), wind (dust, loess) or gravity (colluvium, morain) may be deposited where unwanted and may cause damages. As a result of the hostile conditions (including loss of organic matter) most of the soil biota species, population and activity are seriously reduced. Soil biota is huge in number of species, size and activity functions. There may be both beneficial and deleterious soil flora and fauna. Examples of beneficial species are: symbiotic N-fixing bacteria (rihzobium, nitrobacter); free N-fixing bacteria (azotobacter), actinomycetes and blue green algae; symbiotic fungi (mycorrhiza); organic matter decomposers; soil structure ameliorators (earth worms). Harmful biota species are also many (viruses, bacteria, fungi, nematode, termites…etc) and diverse in effects, some may be both beneficial and noxious.

Anthropogenic causes of land degradation are diverse and of variable magnitude, and the inducing reasons may stem from conscious or unconscious land use practices. Land use practices that may engender degradation may be categorized as deforestation (overexploitation, droughts, and fires), overgrazing, agricultural practices and industrial activities (pollution). The effects produced on soil properties are similar to what is outlined in the above section, but they occur at accentuated and accelerated rates. Land degradation in African is pan-continental and the sub-Saharan zones are the hardest hit by the climate change phenomenon, land degradation and consequences. In fact, the climate instability (erratic rainfall) in Africa is very old and this coupled with concentration of human population, livestock, irrational land use and lack of technologies, particularly in the Savanna zone have led to the land degradation features witnessed nowadays (Diagana 2003; Blay *et al*. 2004; Chidumayo *et al*. 2011). Attempts to quantify the land degradation features, globally, regionally and nationally, are rare and the documented results are fragmentary i.e. not covering all the indices of deterioration and lack consensus. The more comprehensive documentation on the quantification of soil degradation and consequences were reported by Oldeman (1992) and Oldeman *et al*. (1990); a summary of the world and Africa estimates is shown in Table 1. It is obvious that, in Africa, soil degradation by water erosion is greater than wind erosion and that chemical degradation is larger than physical degradation; mean while, the dry zones are the most areas hit by these phenomena.

Table 1: Quantification of soil degradation extent in the world and Africa (M ha)

Degradation features	Total land area (M ha)	Percentage of degraded soils	Dry zone (M ha)	Humid zone (M ha)
Water erosion				
World	1094	56	478	615
Africa	227	46	122	105
Wind erosion				
World	548	28	513	36
Africa	186	38	186	1
Chemical degradation†				
World	240	12	111	130
Africa	62	12	33	29
Physical degradation‡				
World	83	4	35	48
Africa	19	4	14	5

†*Including: loss of nutrients, salinization, pollution and acidification.*

‡*Including: compaction, sealing, crusting, water logging, and subsistence of organic soils. Summarized from Oldeman (1992).*

Oldeman (1992) has also shown estimates of human-induced soil degradation (total land area and causative factors), and from which averages of the world and Africa are successively: 579 and 67 M ha for deforestation; 133 and 63 M ha for overexploitation; 679 and 243 M ha for overgrazing; 552 and 121 M ha for agriculture and 23 and < 1 M ha for industrial activities. In the world Atlas of desertification (UNEP 1997), the following values of land degradation by causative factor for Africa were given as 181.8 M ha for overgrazing; 44.9 M ha for agricultural activity; 53.7 M ha for over exploitation; 11.5 M ha for deforestation and 291.9 M ha for total degraded area. Estimates of soil degradation reported by UNEP (1992) were comprehensive to some extent, and a summary of main findings is given in Table 2. UNEP (1992) has also given soil gradation areas (in $10^3 km^2$) by aridity zones in Africa as: arid 1725; semi-arid 1095 and sub-humid 373 and that totaling to 3193 $10^3 km^2$.

Table 2: Estimated areas of soil degradation by feature index in Africa and the world (in $10^3 km^2$)*

Degradation feature	World	Africa	Degree of percentage (%)
Water erosion	4674	1191	25.5
Wind erosion	4324	1599	37.0
Chemical degradation	1006	265	26.3
Physical degradation	347	139	40.1
Total	10351	3194	30.9

*After UNEP (1992)

Meadows and Hoffman (2003) and Wessels *et al*. (2007) have shown in illustrative forms the extent and causes of land degradation in South Africa and related that to the climatic variation factors. Sudan is also one of the African countries which is severely affected by land degradation caused both by natural and human-induced factors. Considerable land areas are non-utilizable (deserts and rocky mountainous regions) and those under utilization are severely stressed and put out of use. The consequences are numerous and far-reaching, but even witnessing violent arm conflicts in Darfur, Kordofan, Blue Nile…etc. Institutionally, very little is done to face genuinely the problem, although Sudan was among the first African countries to formulate and put in action a national plan for combating desertification (DECARP 1976).

3. Land degradation consequences

Effects of land degradation on human being are many and variable. They can range from reduction of income; food insecurity and famines; health problems; loss of jobs and occupation; loss of habitation and forced displacement-migration; violent conflicts…etc (Scherr and Yadav 1996; Reich *et al*. 2001; MEA 2005; Hendrix and Glaser 2007; Raleigh and Urdal 2007; Obalum *et al*. 2012). Oldeman (1990) has shown that loss of arable land in Africa by different causes between 1985 and 2000 was (in M ha): 25 M ha by desertification; 60 M ha by salinization; 50 M ha by erosion and 150 M ha by road building, urban development and industrialization.

4. Remedies to land degradation

Land degradation problems and consequences can be overcome by many strategies, including short and long-term packages. In fact, people subjected to land degradation, nowadays can face many problems linked to this dilemma. Thus, the short-term steps can include rescuing the affected people by giving food, medical, accommodation and security aid (Scherr and Yadav 1996; MEA 2005; Hendrix and Glaser 2007; Raleigh and Urdal 2007; Lipper *et al*. 2011; Turral *et al*. 2011; Obalum *et al*. 2012). While long-term efforts to cope with the problems of land degradation should begin with establishing national strategies and plans, which should be in harmony with the international conventions and treaties on the subject matter. National awareness must be arisen and appropriate specialized institutions established and mandated to execute the related policies and management plans. At the field level, application of conservation methods and rational utilization should constitute the entries for facing land degradation questions. Where degradation appears to affect the outputs expected from the land, then the adequate measures and technologies should be recurred to in order to sustain land returns. These measures can be used alone or in combination to increase their efficiency. The list is very long but to mention a few like erosion control by mechanical means or planting vegetation; water harvesting techniques; soil fertility replenishment; rational agricultural methods and agroforestry; sustainable exploitation of resources (forests, pastures, controlled open grazing); control of wildfire hazards; strengthening research and training capacities. Definitively, accentuation of land degradation by climate change is not foreseen to be halted in the immediate future. Besides, facing the problems and consequences engendered by land degradation seem to surpass the national and regional capabilities and thus, international efforts should concur to find solutions and mitigate the damaging effects.

References

Allen D.E., Singh B.P. and Dalal R.C. (2011). Soil Health Indicators Under Climate Change: A Review of Current Knowledge (Chapter 2). In: B.P. Singh, A.L. Cowie and K.Y. Chan (Eds.), Soil Health and Climate Change. Springer, http://springer.com/978-3-642-20255-1. 403p.

Arnalds Ó., Bartoli F., Buurman P., Óskarsson H., Stoops G., García-Rodeja E. (Eds.) (2007). Soils of Volcanic Regions in Europe. Springer-Verlag Berlin Heidelberg. 648p.

Blay D., Bonkoungou E., Chamshama S.A.O. and Chikamai B. (2004). Rehabilitation of degraded Lands in Sub-Saharan Africa: Lessons Learned from Selected Case Studies. Forestry Research Network for Sub-Saharan Africa (FORNESSA); International Union of Forest Research Organizations, Special Programme for developing Countries (IUFRO-SPDC). 101p.

Breuning-Madsen H. and Awadzi T.W. (2005). Harmattan dust deposition and particle size in Ghana. Catena 63: 23–38.

Brown K., Hall W.L., Snook M. and Garvin K. (2010). Sustainable Land Development and Restoration: Decision Consequence Analysis. Published by Elsevier Inc, Oxford, UK. 525p.

Brunn S.D. (Ed.) (2011). Engineering Earth: The Impacts of Megaengineering Projects, Vol. 1. Springer Science+Business Media B.V. 2338p.

Buresh R.J., Sanchez P.A. and Calhoun F. (Eds.) (1997). Replenishing Soil Fertility in Africa. SSSA Special Publication Number 51, Soil Science Society of America American Society of Agronomy, Madison, Wisconsin, USA. 264p.

Chidumayo E., Okali D., Kowero G. and Larwanou M. (Eds.) (2011).Climate Change and african forest and wildlife resources. African Forest Forum, www.afforum.org. Printed in Gävle, Sweden. 252p.

DECARP (1976). Sudan's Desert Encroachment Control and Rehabilitation Programme. Prepared jointly by: The General Administration for Natural Resources, Ministry of Agriculture, Food and natural Resources; The Agricultural Research Council, National Convention for Research, in collaboration with UNEP, UNDP and FAO.

Diagana B. (2003). Land Degradation in SubSaharan Africa: What Explains the Widespread Adoption of Unsustainable Farming Practices? Soil Management-Collaborative Research Support Program, Montana State University Tradeoffs Analysis Project in West Africa, Bozeman, MT, USA. 19p.

Eswaran H., Lal R. and Reich P.F. (2001). Land degradation: an overview. In: Bridges, E.M., I.D. Hannam, L.R. Oldeman, F.W.T. Pening de Vries, S.J. Scherr, and S. Sompatpanit (eds.). Responses to Land Degradation. Proc. 2nd. International Conference on Land Degradation and Desertification, Khon Kaen, Thailand. Oxford Press, New Delhi, India.

FAO (1997). Land Quality Indicators and Their Use in Sustainable Agriculture and Rural Development. Proceedings of the Workshop organized by the Land and Water Development Division FAO Agriculture Department and the Research, Extension and Training Division FAO Sustainable Development Department 25-26 January 1996. © FAO, UNDP, UNEP and World Bank 1997.

FAO (2002). Land Degradation Assessment in Drylands-LADA Project. Meeting Report 23-25 January 2002. World Soil Resources Reports 97.

Gisladttir G. and Stocking M. (2005). Land Degradation Control and its Global Environmental Benefits. Land Degradation Development 16: 99–112.

Godone D. and Stanchi S. (Eds.) (2012). Research on Soil Erosion. Published by InTech, Janeza Trdine 9, 51000 Rijeka, Croatia. 200p.

Hendrix C.S. and Glaser S.M. (2007).Trends and Triggers: Climate Change and Civil Conflict in Sub-Saharan Africa. Political Geography 26(6): 695-715.

Lipper L., Neves B., Wilkes A., Tennigkeit T., Gerber P., Henderson B., Branca G. and Mann W. (2011). Climate Change Mitigation Finance for Smallholder Agriculture A guide book to harvesting soil carbon sequestration benefits. FAO. 86p.

Meadows M.E. and Hoffman T.M (2003). Land degradation and climate change in South Africa. The Geographical Journal, Vol. 169, No. 2: 168-177.

MEA (Millennium Ecosystem Assessment) (2005). Ecosystems and human well-being: desertification synthesis: a report of the millennium ecosystem assessment. World Resources Institute, Washington, DC USA. 36p.

Morgan R.P.C. (2005). Soil Erosion and Conservation 3rd Ed. Blackwell Publishing. 316p.

Obalum S.E., Buri M.M., Nwite J.C., Hermansah, Watanabe Y., Igwe C.A. and Wakatsuki T. (2012).Soil Degradation-Induced Decline in Productivity of Sub-Saharan African Soils: The Prospects of Looking Downwards the Lowlands with the Sawah Ecotechnology. Hindawi Publishing Corporation; Applied and Environmental Soil Science Volume 2012, Article ID 673926.

Oldeman, L.R., Hakkeling, R.T.A. and Sombroek, W.G. 1990. World Map of the Status of Human-induced Soil Degradation (GLASOD: Global Assessment of Soil Deterioration): map sheets and explanatory note. ISRIC (International Soil Reference and Information Center), Wageningen, The Netherlands and UNEP, Nairobi, Kenya.

Oldeman L.R. (1992). Global Extent of Soil degradation. ISRC, P.O. Box 353, 6700 AJ Wageningen, The Netherlands; ISRIC Bi-Annual Report 1991-1992, pp. 19-36.

Prospero J.M. and Lamb P.J. (2007). African Droughts and Dust Transport to the Caribbean: Climate Change Implications. Science, Vol. 302: 1024-1027. www.sciencemag.org.

Raleigh C. and Urdal H. (2007).Climate change, environmental degradation and armed conflict. Political Geography 26: 674-694.

Reich P.F., Numbem S.T., Almaraz R.A. and Eswaran H. (2001). Land resource stresses and desertification in Africa. In:Bridges, E.M., I.D. Hannam, L.R. Oldeman, F.W.T. Pening de Vries, S.J. Scherr, and S. Sompatpanit (eds.). Responses to Land Degradation. Proc. 2nd. International Conference on Land Degradation and Desertification, Khon Kaen, Thailand. Oxford Press, New Delhi, India.

Reuveny R (2007). Climate change-induced migration and violent conflict. Political Geography 26: 656-673.

Scherr S.J. and Yadav S. (1996).Land Degradation in the Developing World: Implications for Food, Agriculture, and the Environment to 2020. Food, Agriculture, and the Environment Discussion Paper 14. International Food Policy Research Institute, N.W., Washington, D.C., U.S.A. 42p.

Stanley D.B. (2011). Engineering Earth: The Impacts of Mega engineering Projects. Springer Science+Business Media B.V. 2338p.

Stocking M. and Murnaghan N. (2000). Land Degradation Guigelines for Field Assessment. Overseas Development Group, University of East Anglia, Norwich, UK.

SWCS (Soil and Water Conservation Society) (2003). Conservation Implications of Climate Change: Soil Erosion and Runoff from Cropland. A Report, Iowa, USA. www.swcs.org. 22p.

Swift M.J. and Shepherd K.D. (Eds.) 2007. Saving Africa's Soils: Science and Technology for Improved Soil Management in Africa. Nairobi: World Agroforestry Centre. 28p.

Turral H., Burke J. and Faurès J.M. (2011). Climate change, water and food security. FAO Land and Water Division, Water reports No. 36. 200p.

UNEP (1997). World Atlas of Desertification. UNEP, Nairobi, Kenya. 182p.

UNEP (1992). World Atlas of Desertification. Nairobi: UNEP, and London: Edward Arnold. 69 plates.

Wessels K.J., Prince S.D., J. Malherbe J., Small J., Frost P.E. and VanZyl D. (2007). Can human-induced land degradation be distinguished from the effects of rainfall variability? A case study in South Africa. Journal of Arid Environments 68: 271–297.

WMO (World Meteorological Organization) (2005). Climate and Land Degradation. WMO-No. 989.

Zachar D. (1982). Soil Erosion. Developments in Soil Science I0. Elsevier Scientific Publishing Company. 549p.

Climate Change Adaptation Strategies for Sheep Production in Range Land of Kordofan

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Abstract

Climate changes had great impact on livestock production systems in semi-arid zone. The climate change effect on the stock raised under traditional nomadic system, that involving to extensive seasonal migratory movements for search of water and pasture, the stock of thus subjected of combination of stress such as long journeys, extensive of heat, insufficient water supply, an scarcity and low nutritive quality of pasture particularly during the long dry season.

This study was carried out to decrease the effect of long dry season on sheep productivity in north Kordofan state. A total of 340 ewes and 18 rams of desert sheep were selected from the nomadic herds, animals were divided randomly into four groups, group one was as farmer's practice (not supplement) and the other three groups were supplemented. The breeding is controlled with application of "Kunan" during the breeding season (February to March). Supplementation in the dry season had improved the reproductive and productive performance of the ewes. Lambs borne from group one had less body weight gain. These results of the study indicated the importance of the nutritional status of the animals to adapt the effect of climate chances on rangeland by supplementation strategies during the long

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dry season, also the application of breeding control increased lambing % in the rainy season and growth rate of lambs was improved. The sududy showed that, supplementation and application of Kunan during breeding season are very important strategies to adapt climate change in the rangeland of Kordofan.

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1. Introduction

Sudan desert sheep and their crosses make about 80 % of the sheep found in Sudan and mainly predominant north of 12º N (Devendra and Mcleroy 1982), they are raised mainly under harsh dry land farming conditions for meat production (Khalafalla and Sulieman 1992). The nutritional limitation, low nutritive value of the range, high ambient temperature, scarcity of feed and water are have great effect on the production of the sheep in semi arid area of Kordofan state as compared to that in temperate regions.

The most critical period for grazing sheep in the semi desert zone of Sudan is from February to June, when the ambient temperature becomes hot and range grazing is scanty and depleted of nutrients. Shortage of feed in mating season is the main factor, that effect to sheep production in the range land of Kordofan, taking into account that natural pasture by product are poor in their quality and most the range exposed to over grazing, especially near the water recourses. Seasonal nutritional status and husbandry affect sheep production characteristics (El Hag et al 2001). Nomadic sheep flocks spend the dry season near watering yards. During winter months, when ambient temperature is mild and the range contains some green fodder, herds can extend the watering intervals from 10 to 15 days. After winter grazing when climatic conditions becomes harsh, so the watering interval is reduced to between 3 to 5days (Mukhtar 1985).

Climate changes could impact the economic viability of livestock production systems worldwide. Surrounding environmental conditions directly affect mechanisms and rates of heat gain or loss by all animals. Lack of prior conditioning to weather events most often results in catastrophic losses in the domestic livestock industry. This study was undertaken to reduce the impact of climate change on ewes production and reproductive performance in rangeland of kordofan. The main ultimate objective was to introduce supplementation concept to nomadic herd owners in the dry season.

2. Material and Methods

Study area

The study was carried at Agricultural Research station, El-Obeid, North Kordofan state,(latitude11˚:15-16˚:30 N and longitudes 27˚-32˚ E), Sudan.

Experimental work

A total of 340 desert ewes (1 to 6) years old reared in natural range condition were selected during the normal breeding season (February-March). Ewes were divided into four groups. One group (60 ewes) was used as a control (CTL) (like in farmer traditional practice). The second group (92 ewes) was supplemented with ration A (GNC), the third group (97 ewes) was supplement with ration B (GNC-M) and the fourth group (92 ewes) was supplemented with ration C (RS-M) (Table1). Supplementary feeding practices were imposed on ewes prior to mating (flashing)for 45 days and during late pregnancy (Steaming-up) for 45 days in the long dry season. Mature 18 rams introduced to all experimental ewes, the ratio of the sex were 1:20. All Rams were divided to 3, 5, 6 and for the first, second, third and fourth group respectively, and they were supplemented with same ration B (GNC-M). Rams were allowed to mix with the ewes twice daily: at 6:00 and 18:00 h.

Animals were then allowed to graze normally under range conditions. Ewes were offered 450 g / head of the ration every three days at the watering periods and the rams 600 g / head for three days, ewes fed in small groups in the watering points in period from 6:00 am to 9:00 am and rams were fed individually in the same period. Ewes were monitored for signs of behaviour estrous and those detected were serviced naturally, those returned to estrous were serviced again, ewes demonstrating were naturally mated twice daily at 6:00 and 18:00 h. The experiment extended to 330 days, including 15 days of adaptation period and feeding supplementation period 90 days. Weight of dams was recorded during mating, mid-pregnancy and late-pregnancy time. The body condition score (BCS) was determined according to 1 to 5 scale (Russel 1991) and recorded in breeding, mid pregnancy and lambing period. The lambs were weighed after birth, then at 15, 30, 45,60,75,90,105 and 120 days of age. Born lambs were identified by ear tag to follow lamb growth rate every 15 days till 120 days of lamb age.

Control breeding by application of (Kunan)

The control of breeding is by tied the reproductive organs of the ram (Kunan), this is a common practice to control breeding which is usually carried out during (February-March) with subsequent lambing during autumn (July-September). This practice would ensure good grazing for lambs. However, weaned lambs may be exposed to long dry winter and summer period when agricultural by products and residues, especially groundnut seed cake and hay are widely used by sheep owners.

Statistical analyses

Data were analyzed by least square mixed model (Harvey 1990).

Analytical procedures

The analysis performed to experimental rations according to A.O.A.C. (1995) and Goering and Van Soest (1991). The content of the metabolizable energy (ME, MJ / kg DM) was calculated from table values of energy content of the components according to A.O.A.C. (1995).

3. Results

All treatments improved ($P < 0.05$) ewes BCS in mid pregnancy and at birth compared with farmers practice (Table 2). Ewes in first, second and the third parity number loss more ($P < 0.05$) condition in parturition than of their fourth and fifth parity. Sex of lamb and birth type had significant ($P < 0.05$) effect on ewes BCS, ewes born male lambs were lost more BCS than ewes born female lamb, dams born twins lost more BCS compared with that born single.

Table 1: Chemical composition (g/kg dry matter) of the supplements and calculated energy content

Ingredients	Ration A (GNC)	Ration B (GNC-M)	Ration C (RS-M)
Molasses	–	10	10
Roselle seeds	99	89	–
Groundnut seed cake	–	–	89
Common salt	0.75	0.75	0.75
Salt lick	0.25	0.25	0.25
Nutrient (g/kg DM)			
Dry matter	941	940	942
Crude protein	557	504	303
Crude fibre	72	65	144
Crude fat	72	66	212
Ash	52	55	101
NFE	247	310	240
NDF	129	116	244
ADF	95	86	169
ADL	15	13	61
g Ca/ kg DM	0.73	0.74	2.16
g P/ kg DM	5.42	4.87	4.42
Energy density (ME, MJ/kg DM)	12.5	12.4	13.1
In vitro OM digestibility (%)	80.9	87.7	62.2

ME metabolizable energy calculated from literature values.

GNC Ground nut cake; GNC-M Ground nut cake and Molasses ; RS-M Roselle seeds and Molasses ; CTL Control

Pre-partum supplementation of the dams had significant ($P<0.05$) effect on lamb daily growth rate (Table 3). In general, ewes' pre-partum supplementation improved lambs daily growth rate and there were significant ($P< 0.05$) difference in lamb growth before and after weaning. lambs whose dams were supplemented with RS-M had slightly higher growth rates, also the study revealed that supplementation had no significant ($P> 0.05$) effect on lambs growth rate in the intervals 90-120 days of age (after weaning). Type of birth and sex had significant effect on daily lamb growth rate (figure 1 and 2), also dam parity had significant effect on lamb growth rate (figure 3).

Table 4 presents the effect of pre-partum supplementary feeding on lamb weight from birth to 120 days of age. During long dry period, supplemented dams had heavier ($P<0.05$) lambs weight than the farmer practice (control), dams supplemented with GNC significantly had ($P<0.05$) heavier lambs at 120 days than those supplemented with GNC-M and RS-M. Dam parity had significant effect on lamb birth weight; late parties were significant difference from the other parties'. Type of birth had significant ($P < 0.05$) effect on birth weight and over all age period, single lambs were significantly heavier than twins. Male lambs recorded significantly ($P < 0.05$) heavy weight at birth to 120 days of age than female lambs.

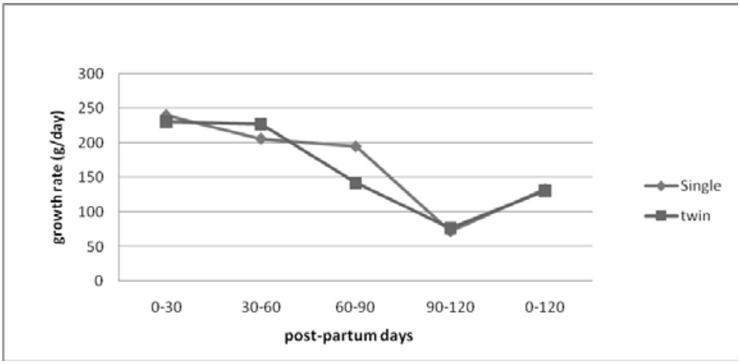

Figure 1: Effect of birth type on lamb growth rate (g ⁄day)

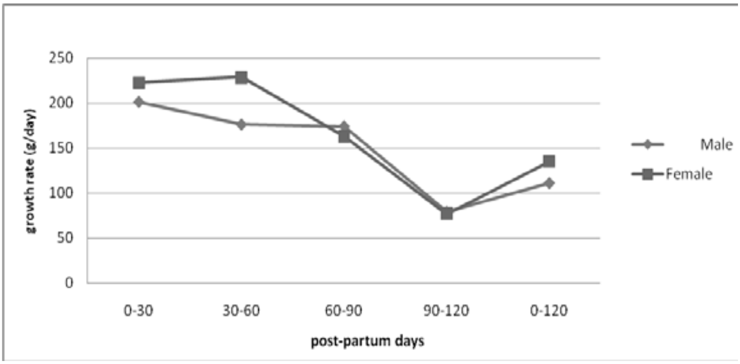

Figure 2: Effect of sex on lamb growth rate (g ⁄day)

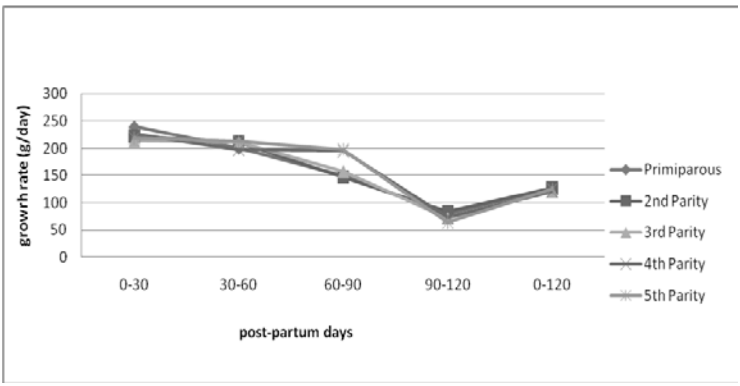

Figure 3: Effect of parity number on lamb growth rate (g ⁄day)

4. Discussion

In lambing season, the BCS was reduced in the animals. During this period the nutritive value of the forage are low and the supplements are not enough for ewe maintenance and fetal growth .Under such conditions, it would be expected that the ewes would have used their body reserves to meet the increased nutrients demand for final fatal growth. Concentrate supplementation might also decrease the loss of body reserves. These are similar with results of Sairanen et al (2006) and. In late gestation, ewes on farmer's practice were grazed on fibrous forage of low nutritive value without any concentrate supplementation. Inadequate feed intake during late pregnancy has been found to cause a reduction in birth weight, mammary gland development and milk production. Similar results were obtained by Mellor and Murray (1985). Lambs whose mothers were treated with supplementation had higher body weight than lambs suckling control ewes; this explanation is in line with findings of Rafiq et al (2006). Dam parity had an influence on lamb birth weight, lambs born on fifth parity recorded heaviest weight than the other parities and ewes on fourth parity born had lightest lambs. The results also indicated that, dam parity had no significant effect ($P > 0.05$) on lamb weight in the interval, 15 days to 120 days, this may be due that lactation curve. In this study sex of lamb had significant ($P < 0.05$) effect on lamb weight, single lambs recorded heavier weight than twins and male lambs were heavier than female lambs, these results are in general agreement with research workers, Hassen et al (2002) . On the contrary El-Toum (2005) indicated that, Lambs sex had no significant effect on lamb weight at birth, 45, 60 and 75 days of age. Similar results were obtained by Schoeman et al (1993). Type of birth had significant effect on lamb weight at birth and over all age period, similar results were obtained by Cloete et al. (2007). Ewes' pre-partum supplementation improved lambs growth rate before weaning (0-90). Hence lambs born to ewes with supplementation had highest growth rate than those suckling non supplemented ewes (framer's practice), Supplementation of pregnant ewes during late gestation may provide adequate energy and protein to support maintenance of animal physiological needs, mammary gland growth, colostrums and milk yield. This result was in line with findings of Oeak et al (2005). In this study, higher growth rates in lambs suckling supplemented ewes is expected to increase milk production as supported by observations by Rafiq et al (2006). Supplementation had no effect on lambs' growth rate after weaning (90-120 days of age). This may be due to the short lactation period of the desert sheep. The sex had no effect on lambs' growth rate in the intervals 90-120 days of age. Similar results were obtained by El-Hag et al (2001). Male lambs indicated higher growth rate only in the interval 60–90 days.

Table 2: Main effect of supplementation and Parity Number on body condition score (mean± S.E) of desert ewes at different physiological states.

Factor		BSC at mating	BSC at mid pregnancy	BSC at lambing
Treatment	GNC	2.6±0.04 ^{c}	2.6 ±0.05 ^{a}	2.3±0.07 ^{a}
	GNC-M	2.9±0.04 ^{ab}	2.7±0.05 ^{a}	2.2±0.06 ^{a}
	RS-M	2.9±0.04 ^{ab}	2.6±0.06 ^{a}	2.0±0.08 ^{b}
	CTL	2.8±0.05 ^{bc}	2.5±0.07 ^{b}	2.1±0.10 ^{b}
Dam parity	Primiparous	2.9±0.04 ^{a}	2.7±0.07 ^{ab}	2.1±0.07
	2nd parity	2.7±0.05 ^{bc}	2.5±0.06 ^{c}	2.2 ±0.08
	3rd parity	2.8 ±0.03 ^{b}	2.6±0.04 ^{ab}	2.0±0.05
	4th parity	2.7±0.04 ^{c}	2.5±0.06 ^{c}	2.1±0.07
	5th parity	2.7±0.07 ^{bc}	2.6±0.09 ^{ab}	2.3±0.12
overall mean		2.8±0.01	2.6±0.02	2.2±0.02

^{abc} *means in the same column bearing different superscripts are significantly different (P<0.05)*

GNC: Ground nut cake; GNC-M: Ground nut cake and Molasses ; RS-M: Roselle seeds and Molasses ; CTL: Control; N: Number of animals

Table 3: Effect of pre-partum supplementary feeding on lamb growth (mean ±S.E) g ⁄day.

Treatment	0–30 days	30–60 days	60–90 days	90–120 days	0–120 days
GNC	229 ± 16 [a]	204 ± 22 [b]	182± 16 [a]	71 ± 13	127 ± 6 [a]
GNC-M	225 ± 17 [a]	204 ± 23 [b]	173 ± 17 [ba]	79 ± 14	125 ± 6 [a]
RS-M	226 ± 18 [a]	229 ± 25 [a]	156 ±18 [c]	70 ± 15	130 ± 7 [a]
CTL	217 ± 19 [b]	189 ± 26 [c]	168 ±19 [abc]	77 ± 16	116 ± 7 [c]

[abc] *means in the same column bearing different superscripts are significantly different (P<0.05)*

GNC Ground nut cake; GNC-M Ground nut cake and Molasses ; RS-M Roselle seeds and Molasses ; CTL Control

5. Conclusion and Recommendation

The study indicated that, flushing and steaming-up during breeding period improved the body condition and lambs born from supplemented ewes recoded better production characteristic compared with farmer's practice. The study indicated the importance of the nutritional status of the nomadic ewes at mating and supplementation reduced the effect on the climate chance on productive and reproductive performance. Supplementation and application of Kunan during breeding season are very important strategies to adapt climate change in the rangeland of Kordofan.

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References

A.O.A.C. (1995) Association Official Analytical Chemical Methods of Analysis .16th endo.

Cloete, J.J.E., Cloete, S.W.P., Olivier, J.J., Hoffman L.C. (2007) Terminal crossbreeding of Dorper ewes to Ile de France, Merino Landsheep and SA Mutton Merino sires: Ewe production and lamb performance. Small Ruminant Research 69, 28–35.

Devendra, C. and Mcleroy, G.B. (1982) Goats and sheep production in the tropics .London Longman Singapore Publishers, London.

El-Hag, F.M., Fadlalla, B. and Mukhtar, H.K. (2001) Some production characteristics of Sudan Desert sheep under range conditions in North Kordofan. Sudan. Tropical Animal Health and Production 33, 229-239.

El-Toum, A. (2005) Effect of pre-partum supplementary feeding on desert ewe productivity under rangelands in north Kordofan, Sudan. M.Sc. Thesis, University of Khartoum.

Goering, H. and Van Soest, P. (1991) Nutritional aspect of dietary fibres. Animal Feed Science Technology 32, 143 - 158.

Harvey, W.R. (1990) User guide for LSML (Least Squares Maximum Likelihood) computer program. Ohio, USA.

Hassen, Y., Sölkner, J., Gizaw, S. and Baumung, R. (2002) Performance of crossbred and indigenous sheep under village conditions in the cool highlands of central-northern Ethiopia: growth , birth and body weights. Small Ruminant Research 43, 195-202.

Khalaffala, A.M. and Sulieman, Y.R. (1992) Some observations on reproductive traits in the flock of Sudan Desert sheep. Sudan Journal of Animal production 5, 81− 86.

Mellor, D.J. and Murray, I. (1985) Effects of maternal nutrition under development during pregnancy on colostrums production in Scottish Black face ewes with twin lambs. Research Veterinary Science 39, 230 -234.

Mukhtar, H.K. (1985) Constrains of desert sheep production in the sedentary and nomadic systems of north Kodofan. Annual Research Report ElObied Research Station, Agricultural Research Corporation (ARC), Wad Medani, Sudan, 40 –55.

Oeak, N., Cam, M.A. and Kuran, M. (2005) The effect of High Dietary protein levels during late gestation on colostrums yield and lamb survival rate in singleton-bearing ewes. Small Ruminant Research 56, 89-94.

Owen, J.G., Norman, G.A., Fisher, I.L. and Frost, R.A. (1977) Studies on the meat production characteristics of Botswan goats and sheep. part 1. Sampling, methods and materials, and measurements on the live animals. meat Science 1, 63- 69.

Rafiqa, M., Mumtazb, S., Akhtar, N. and Khana, M.F. (2006) Effect of strategic supplementation with multi-nutrient urea molasses blocks on body weight and body condition score of Lohi sheep owned by tenants of Pakistan. Small Ruminant Research 61, 29–38.

Russel, A. (1991) Body condition score of sheep, sheep and Goat practice 3

Sairanen, A., Khalili, H. and Virkajarvi, P. (2006) Concentrate supplementation responses of the pasture-fed dairy cow. Livestock Science 104, 292–302.

Schoeman, S.J., De Wet, R. and Van der Merwe, C.A. (1993) Assessment of the reproductive and growth performance of two sheep composites, developed from the Finnish Landrace, compared to the Dorper. South Africa Journal of Animal Science 23, 207-210.

Sulieman, A.H., Sayers, A.R. and Wilson, T.R. (1990) Evaluation of Shugor, Dubasi and Watish of Sudan Desert sheep at El_Huda National sheep Research Station, Gezira Province, Sudan. International Livestock Centre for Africa (ILCA) Research Report 18, 1-13.

Soil Trends under the Gum Cultivation Cycle

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Abstract

The gum cultivation cycle is a form of traditional agriculture in the low rainfall Savanna zone of Sudan. Essentially gum trees are cleared for cultivating traditional field crops such as sorghum, sesame, millet; ground nuts, roselle etc When crop yields decline, the fields are abandoned for another adjacent location. The abandoned plots are gradually recolonized by gum tree (*Acacia senegal*, L.). Most researchers on gum cultivation agroforestry maintain that *Acacia senegal* trees do rejuvenate the soil through litter mineralization, This paper high-lights the main soil nutrients status in a typical site- Eldemokeya Forest Reserve in Northern Kordofan. at two periods : year 1975 whence the initial soil sampling was done and year 2005 when soil samples were collected from the same site at three depths for laboratory analysis of selected parameters at standard techniques. Results of 2005 research showed that most of soil mineral concentration was on the surface layer (0-20 cm) which was significantly higher than the layers below particularly soil carbon and nitrogen. Moisture content increases with soil depth. Differences in soil PH were not significant. This is in agreement with most researches done in the same locality. Comparison of this data with that of 1975 sampling at the same forest reserve showed that there is a great decline in soil chemical attributes concentration particularly organic carbon and nitrogen. Yet inter-cropping maintains higher concentrations of C and N relative to sole cropping. Organic carbon

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in- puts were considerably higher in inter- cropped systems because of the high in-puts from tree bio-mass;..Soil P and K were significantly higher under inter- cropping. There is a low soil carbon increase during the fallow and faster carbon decrease during cultivation. In spite of the deterioration of soil fertility over the decades ,the economic analysis based on Land Equivalent Ratio suggested that inter- cropping agricultural crops with *Acaci*a *senegal* maintains the upper hand attaining positive L.E.R. advocating Gum Cultivation Agroforestry System as the best option for sustainable resource management in these desertification prone sectors.

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1. *Introduction*

The gum- cultivation cycle is a form of shifting cultivation practised traditionally in the low- rainfall Savana Zone of Sudan. Essentially old gum trees are cleared for cultivation of traditional field crops such as ground nuts, sesame, sorghum, millet, roselle, water mellons etc. The field plots are then abandoned when yields decline to be recolonized by the gum trees and after about 10 years of gum tapping, cultivation commences again. The cycle is well described by Hussein (1990).It has been indicated by several authors that *Acacia senegal* rejuvenates the soil through litter mineralization (Husein, 1990 ;Eltuhami, 1998). It was, however reported recently by some workers (e.g.Eltahir, 2006) that there is a nutrient depreciation in sandy soils of North Kordofan- precisely in the Agricultural Research Corporation field station at Eldemokia forest reserve. This study was under taken in Eldemokya forest reserve to elucidate the forest nutrient status under inter-cropping for decades with traditional field crops.

2. Materials and Methods

Two inter-cropping experiments were conducted at Elobeid Research Farm and Eldemokia site in a 15 year old plantation of *Acacia Senegal* with average crown widths of 276 cm and 205 cm in a randomised complete block design with 4 replicates. Soil is sandy , rainfall 200-350 mm during July-September, mean relative humidity 34 %, mean annual and maximum temperature ranges between 20° and 35° C. Treatments were: Sole trees at 5m * 5m spacing, sesame with trees, ground nuts with trees, rozelle with trees, sole ground nuts, sole sesame, sole rozelle. Seeds were obtained from Elobeid Agricultural Research Centre. Each plot was 10*10 m separated by 2m alleys and 5m between blocks. Before sowing seeds were treated with Furmisan D against soil fungi and insects .Seeds were sown during July at a spacing of 60*.20cm,50*.30cm and 50*.50cm for ground nuts, sesame and rozelle respectively at seed rates of 2 seeds per pit for roselle and ground nuts,3 seeds per hole for sesame as per Elobeid Agricultural Research Centre prescription. Two weedings were done after 2 and 5 weeks from planting.

Soil samples were collected at depths of 0-20 cm, 20-40 cm and 40-60 cm. Each Block was divided into six plots-3 plots for alley cropping and 3 plots for sole cropping (control).The area of each plot was 15*.15 meters. Each alley plot contained 14 trees on the average .The plots were cleared of undesirable vegetation and fenced as necessary and were then laid down during June and seeds sown during July after testing for germination. Plant holes were dug with a hoe at different spacings using the recommended seed rates for each crop as per the agricultural research standards. The samples were air-dried and sieved through a 2 mm- mesh. Then the following parameters were determined at Elobeid Agricultural Research Centre according to USDA hand book No 60: PH by PH- meter in soil paste (1:5 Soil:Water), P by Spectro- photometer using Na HCo3 methods, organic carbon by Walkley and Black (organic matter = C*1.92), Nitrogen by macro-Kjeldahl method (Person, 1970) Textural classes were assigned according to USDA System 1975

Residual soil moisture was measured during July-August-September gravimetrically at 20, 40, 60 cm soil depths. The soil samples were oven-dried at 105° Celsius for 24 hours and subsequently soil moisture calculated on dry weight basis. Statistical analysis for agronomical data was done by computer program MSTAT-C Statistical Package (Fisher 1990) and L.S.D for significant differences.

3. Results and Discussion

Most of the soil mineral concentration is on the surface soil layer 0-20 cm (table 1). Significant differences are indicated between the surface soil layers and the layers beneath. Similarly between inter-cropping and sole-cropping systems. There was no significant difference in PH levels. Soil organic carbon is relatively higher under inter-cropping. This is in agreement with the accumulation pattern found for this species (Hussein, 1990, Hussein and Eltuhami,1998.Deans et al,1999 and Gerakis and Tsangeraskis,1970). K levels are also slightly higher in intercropping systems compared with sole cropping .The result agrees with Deans et. al. (1999) who found that both P and K were much higher in inter-cropping systems than sole-cropping. Comparing surface soil nitrogen and carbon percentage of the present study with the 1975 sampling at the same forest (Hussein, 1983) showed that there is a great decline in soil chemical attributes concentration particularly organic carbon and nitrogen. This is due to continuous cultivation and shortening of the bush fallow to meet population growth and the demand for food especially during the drought years. Soil analysis under the gum cultivation system in Eldemokeya forest reserve gave the following:

Table 1. Main chemical attributes 0-20cm layer- season (2004)

Cultivation system	O.C	N	P	K	PH
Inter-cropping	0.24	0.019	2.38	0.13	7.30
Pure *Acacia senegal*	0.20	0.016	2.014	0.12	7.30
Sole cropping	0.18	0.013	1.24	0.12	7.20
S.E.	0.03	0.002	0.05	0.02	0.03

Most of soil mineral concentration is in the surface soil layer (0-20 cm). Significant differences are indicated between the surface soil layers and the soil layers beneath. Similarly between inter-cropping and sole cropping systems in O.C. and N. There was no significant difference in PH levels.

Table 2. Main soil chemical attributes 0-20,-20-40, 40-60cm. layers

Layer (cm)	O.C.	N	P	K	PH
0-20	0.24	0.19	2.5	0.14	7.4
20-40	0.19	0.015	2.3	0.12	7.3
40-60	0.18	0.013	2.2	0.11	7.2
Mean	0.20	0.016	2.3	0.12	7.3

Table 3: Effect of cropping system on the moisture content (mm) in 0-20,20-40, 40-60cm soil layers at Eldemokeya forest reserve,North Kordofan, season 2004

Cropping System	Soil Depth (cm)			Mean
	20	40	60	
Sole ground nuts	9.1	19.9	29.3	19.4
Sole sesame	7.9	17.1	22.4	15.8
Sole roselle	5.8	14.4	20.1	13.4
Sole *Acacia senegal*	3.9	12.9	17.1	11.3
Ground nuts inter-cropped	2.2	11.2	14.3	9.2
Sesame inter-cropped	1.4	9.3	11.2	7.3
Roselle inter-cropped	0.98	7.3	8.6	5.6
Mean	4.5	13.2	17.6	
S.E.	1.18	1.50	2.6	

Moisture content increases with soil depth showing means of 4.5mm at 20 cm depth, 13mm at. 40 cm depth and 17.6 mm at 60 mm depth (table 3). Sole cropping maintains more moisture content than inter-cropping obviously because the deeper tree roots siphon a lot of water up the wider tree crown that transpires more moisture than agricultural crops in between.

Comparing surface soil nitrogen and carbon of the present study with the1975 samples at the same forests (Hussein,1983) showed that there is a great decline in soil chemical attributes concentration particularly organic carbon and nitrogen viz:. 1975: Carbon 0.33, Nitrogen 0.30; 2005: Carbon 0.24, Nitrogen 0.019.

There is an appreciable decrease in soil Nitrogen and Organic Carbon which is attributed to intensive cultivation. Soil Phosphorus and Potassium levels were slightly higher under inter-cropping. Similar results were obtained by Deans et.al. (1999) for the same species in plantations aged 3-18 years old in Northern Senegal.

According to Eltahir (2006), main in-puts of organic matter were tree roots, leaves, and grass and crop roots. Out-puts were crop products, residues, grass shoots, erosion. Carbon inflows were significantly higher in all inter- cropped systems irrespective of tree density compared to pure crops and pure grass . In inter- cropped grass , in-puts from trees contributed about 90% of Carbon while grass roots contributed about 10%. In inter-cropped sorghum systems, about 99% of Carbon in- puts were from trees while 1% was from Sorghum roots. In inter- cropped Roselle systems, about 96% of Carbon in-puts were from trees and 4% from Roselle roots.

Organic Carbon in-puts were considerably high in inter-cropped systems because of the high in-puts from tree biomass. Out-put flows were significantly higher in the Sorghum system (2328 kg /ha/yr) followed by Roselle then grass. It is important to elongate the tree fallow as long as possible. Successive cultivation results in rapid deterioration of biological, chemical and physical soil properties.

According to Ardo and Olson (2004), there is a significant negative relationship between cultivation intensity and soil organic matter in the semi-arid sandy soils in North Kordofan in the upper 20 cm layer.

There is a low soil carbon increase during the fallow and faster soil carbon decrease during cultivation. Crop land and grass fallow decrease soil carbon by 9.4 and 8.4 kg./ha/yr while Savanna (Trees + Grass) increases soil organic carbon by 7.5 kg/ha/yr. Grass fallow does not restore soil fertility well because a short fallow of weedy annual species leaves the soil bare to erosion in the dry season.

4. Conclusion

In-spite of the deterioration of soil fertility over the decades, the economic analysis based on Land Equivalent Ratio reported by Fadl (2007) suggests that inter-cropping agricultural crops with *Acacia sengal* maintains the upper hand giving positive Land Equivalent Ratios. In dry lands such as North Kordofan where droughts are recurrent and desertification is over-whelming, the Gum – Cultivation Agroforestry System is the best option.

References

Ardo. P. and Olson, L. (2004) Soil carbon sequestration in traditional farming in Sudanese dry lands. *Environmental management* 33 supplement 1, 318-329 .

Buresh, R.L. and Tian, G. (1998) Soil improvement by trees in Sub-Saharan Africa. Agroforestry systems.

Deans, J.D., Diagne, O. Lindley, D.K., Dione, M. and Parkinson, J.A. (1999) Nutrient and organic matter accumulation in Acacia Senegal fallows over18 years. *Forest Ecology and management* 124, 153-167.

El-Tahir B.A. (2006) Nutrient balance in traditional farming system involving Acacia senegal agroforestry in semi-arid sandy soils of North Kordofan-Sudan. Ph.D. thesis, University of Khartoum.

Fadl, K.M. (2007) Bio-investigations in the gum- cultivation cycle in North Kordofan. Ph.D. thesis, DADCSI- University of Khartoum.

Gafar, A. (2005) Improvement of traditional Acacia senegal agro-forestry: Ecophysio-logical characteristics as indicators for tree-crop inter-action on sandy soils in Western Sudan. Ph.D. thesis, University of Helsinki.

Gerakis, P.A. and Tzangerakis, C.Z. (1970) The influence of *Acacia senegal* on the fertility of a sand sheet soil in central Sudan. *Plant and soil* 33, 81-86.

Hussein, S.G. (1983) A preliminary study of soils under *Acacia Senegal*(L)Willd. *Sudan Silva* 5, 125-135.

Hussein, S.G. (1990) The influence of fallow under *Acacia Senegal* (L.) Willd on carbon and N content of the soil. *Beitrag Tropische Landwirtschaft* 28, 217-223.

Hussein S.G. and El-Tuhami, A.E. (1998) The influence of *Acacia Senegal* plantations on some properties of a Vertisol soil. *Social forestry and environment* 4.

Institutional and Spatial Arrangements for Sustainable Forest Management

Forest Management Units on Ground - Approaching Factors and Drivers for Best Practice Sustainable Forest Management

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Abstract

Despite the promotion of sustainable forest management for decades, the degradation of tropical forests continues. Many forest management units seem not being able to control degradation and to sustain the tropical forests. Following a positive approach by not looking on problems but on assets, factors for successful, sustainable forest management by forest management units are identified from literature. The identified drivers could be used for the design of efficient actions to promote sustainable forest management by the forest management units. The paper presents the results from a literature review, a conceptual framework and identifies groups of factors for future research.

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1. Introduction

There is a great awareness about the alarming rates of deforestation on a global scale: approximately 13 million hectares have been deforested between 2000 and 2010 (FAO 2011). The annual loss for

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Africa alone is approx. 3.5 million hectares for the period 2005 to 2015; key drivers are: population growth, poverty, economic growth, land pricing, international demand for timber and other forest products, insecurity of the rights of local people, and incomplete valuation of forest ecosystems (UNEP 2012, p. 72). Barriers against sustainable forest management (SFM) in tropical countries include: competition with illegal logging, land rights limited in time (concessions, leaseholds), high capital cost, and lack of skilled workers. Those hindrances are found at national, regional and local levels (Galante et al. 2012, p. 61). Mwavu and Witkowski (2008, p. 610) identified the following drivers for land-use and land-cover changes in Uganda: rapid human population increase, associated with agricultural expansion for cash crop as well as for subsistence crop cultivation, unclear land tenure, and political intervention in the management of both, private and gazetted forests/woodlands reserves, including the degazetting of forest reserves.

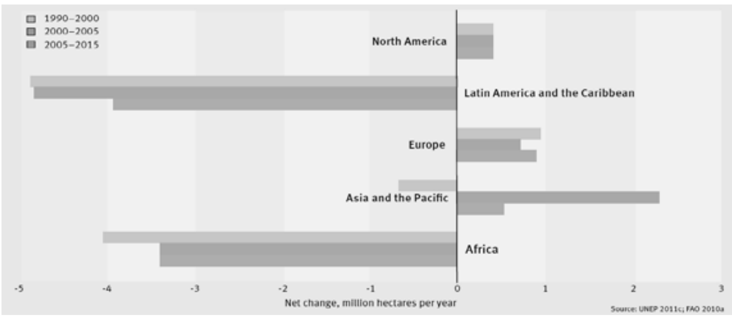

Figure 1: Change in forest area by region, 1990 – 2010
Source: (FAO 2010; UNDP 2011 cited from UNEP 2012, p. 72)

The motivation for the topic of the paper is to identify the useful assets and design features which enable and/or support forest organizations in performing *sustainable* forest management. Hence, the approach is not focusing on destructive forces and elements, but on constructive ones. This is in contrast to the frequently studied drivers for deforestation. The paper focus on components which could be strengthened enforced and supported. Following a positive approach, factors which could be supported or initiated to contribute to sustainable forest management and to the maintenance of the forests are of major concern. The findings shall enable practitioners to implement more efficient interventions supporting SFM - in a nutshell: to provide options to maintain forests by building effective, resilient institutions and organizations for forest management.

Research questions corresponding to this objective are: (1) How to determine the best practice of SFM, (2) what are the factors and drivers for such best practice SFM and (3) how to identify them?

To achieve this task, literature was reviewed and a conceptual frame for the analysis of SFM factors and drivers is presented and discussed.

2. Literature review

2.1. Forest management units (FMU)

Forest management units on the ground are understood as forest management *organizations,* referring to a formal or informal enterprise or an institutional arrangement to implement forest management operations on ground. This includes a variety of communities, groups, smallholders, operators, forest companies, large private and public forest land holdings with their individual arrangements for forest management operations (see also Auch et al. 2014).

2.2. Factors and drivers

In the dictionary a factor is defined as "a circumstance, fact, or influence that contributes to a result" (Oxford Dictionaries undated). Such a factor can be passive or active. A driver refers to "a factor which causes a particular phenomenon to happen or to develop" (ibid.). So the driver is a factor dominating a complex process, in the meaning that it is active and it transmits motion. Linking back to the aim of the paper: knowing these factors would provide entry points for supporting SFM.

To evaluate sustainable land management, the FAO (1993, pp. Level 3) sees the terms *factor*, *attribute* and *characteristic* as interchangeable and deliberately accepted to be vague. Their meaning can address either things, processes, constraints or concepts; which may be expressed as quantitative or qualitative. By contrast, the same source uses the term *criteria* to describe mathematical functions or other rules and relationships of causalities', linking different factors and enabling a prediction of direction and magnitude of change/ results.

2.3. Best practice

Best practice indicates a high quality, it refers to "commercial or professional procedures that are accepted or prescribed as being correct or most effective" (Oxford Dictionaries undated). Best practice is sometimes fine-tuned in *best* – and in *good practice*, is the reference level for evaluation of a particular practice. Usually it draws on the different ways the same thing are (or could be) done by the different actors.

2.4. Sustainable forest management (SFM)

ITTO (2011, p. 19) recently defined *sustainable forest management* (*SFM*) very comprehensively as "the process of managing permanent forest land to achieve one or more clearly specified objectives of management with regard to the production of a continuous flow of desired forest products and services without undue reduction in its inherent values and future productivity and without undue undesirable effects on the physical and social environment".

SFM was established as a tool to ensure continuous production of main forest products (timber and firewood) after overexploitation of forests in Europe some 300 years ago (Carlowitz 1713)[*]. It became global main stream after the publication of the Brundtland report (Brundtland 1987) when many other disciplines adopted the concept of sustainability. Some authors consider only the late 1980s as start of SFM (Daniels et al. 2010, pp. 51–52; Kotwal et al. 2008, p. 104). In fact, the focus of SFM management goals moved from *production* to the *forest-ecosystem* as such. Kotwal (ibid.) sees SFM as "ecologically sound practices that maintain the forest ecosystem's integrity, productivity, resilience and biodiversity" From the conventional SFM of the forest ecosystems with a management for desired products and functions[†], the notion shifted SFM as management for maintaining the forest ecosystem. It shall remain in, or it shall be brought back into a good state, able to deliver the required services like conservation of biological diversity and social and economic matters. According to Monserud (2003, p. 36) this shift from sustained yield to sustainable forestry is a shift in attitude. Similar, McDonald and Lane (2004, p. 64) found that under SFM new paradigms of forest management have been emerged and it is "a new way of thinking" (ibid, p. 68). Galante et al. (2012, p. 60) designed a hierarchy of production forest management, based on experience with concessions in Malaysia and on carbon payments as mechanism for development (Fig. 2). The idea is that each higher management level is a direct function of the previous level (tier). The levels are: conventional or *Business-As-Usual* harvesting, reduced impact logging (RIL), forest certification, and SFM. Interestingly, the authors handle SFM separate from RIL and from certification. They placed it on top of the quality pyramid, as "ideology, vision and founding principle of forest management, designed to recognize and address the differentiation of forest management approaches through balanced,

[*] Not meaning that this was necessarily the first or the only place employing this concept.
[†] Functions in the understanding of AGFE-AGLP (1982) "effects/impacts of forests coincidently with functional contributions for the superior social system" – so, there is a significant value added created for the society, (ecosystem) services are seen as "all effects/impacts of forests delivered, regardless of their collective acknowledgement and esteem by society".

sound, holistic environmental, social and economic values which contribute to sustainable development" (Galante et al. 2012, p. 61).

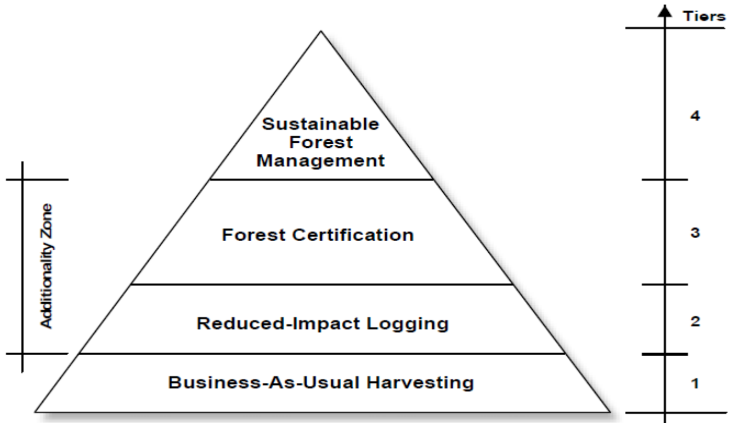

Figure 2: Hierarchy of production forest management.
Source: Galante et al. (2012, pp. 60)

To sum up, SFM is the acknowledged concept or principle to maintain forests in a good state, which may include goals for production, function and services. It is not indicating that SFM is a concept to prevent conversion of forest land in other land uses. This aspect is considered by ITTO with the definition of the category of *permanent* forest land, and plays a prominent role in the conceptual framework (Fig. 2) in Chapter 4.

2.5. Assessment and evaluation of SFM

To operationalize the concept of SFM, comprehensive sets of criteria and indicators (C&I) have been compiled. C&I are used to assess and evaluate the outcomes/results or performance of SFM. In nine ongoing regional/international processes* criteria and indicators with seven

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* "Dry-Zone Africa Process on Criteria and Indicators for Sustainable Forest Management; International Tropical Timber Organization; Lepaterique Process of Central America on Criteria and Indicators for Sustainable Forest Management; Montreal Process on Criteria and Indicators for the Conservation and

thematic elements for sustainable forest management have been developed (Box 1) and fine-tuned in the last two decades. McDonald and Lane (2004) found an emerging consistency and convergence between the nine processes in their development of the C&Is.

Box 1: Thematic elements of sustainable forest management

"**1. Extent of forest resources**

The theme expresses an overall desire to have adequate forest cover and stocking, including trees outside forests, to support the social, economic and environmental dimensions of forestry. For example, the existence and extent of specific forest types are important as a basis for conservation efforts. The theme encompasses ambitions to reduce deforestation and to restore and rehabilitate degraded forest landscapes. It also includes the important function of forests and trees outside forests to store carbon and thereby contribute to moderating the global climate.

2. Biological diversity

The theme concerns the conservation and management of biological diversity at ecosystem (landscape), species and genetic levels. Such conservation, including the protection of areas with fragile ecosystems, ensures that diversity of life is maintained, and provides opportunities to develop new products in the future, including medicines. Genetic improvement is also a means of increasing forest productivity, for example to ensure high wood production levels in intensively managed forests.

3. Forest health and vitality

Forests need to be managed so that the risks and impacts of unwanted disturbances are minimized, including wildfires, airborne pollution, storm felling, invasive species, pests, diseases and insects. Such disturbances may impact social and economic as well as environmental dimensions of forestry.

4. Productive functions of forest resources

Forests and trees outside forests provide a wide range of wood and non-wood forest products. This theme expresses the ambition to maintain an ample and valuable supply of primary forest products, while at the same time ensuring that production and harvesting are sustainable and do not compromise the management options of future generations.

Sustainable Management of Temperate and Boreal Forests; Near East Process on Criteria and Indicators for Sustainable Forest Management; Pan-European Forest Process on Criteria and Indicators for Sustainable Forest Management; Regional Initiative for the Development and Implementation of National-Level Criteria and Indicators for the Sustainable Management of Dry Forests in Asia; and the Tarapoto Proposal of Criteria and Indicators for Sustainability of the Amazon Forest" (FAO 2006: 4).

5. Protective functions of forest resources

The theme addresses the role of forests and trees outside forests in moderating soil, hydrological and aquatic systems, maintaining clean water (including healthy fish populations) and reducing the risks and impacts of floods, avalanches, erosion and drought. Protective functions of forest resources also contribute to ecosystem conservation efforts and have strong cross-sectoral aspects, because the benefits to agriculture and rural livelihoods are high.

6. Socio-economic functions

The theme covers the contributions of forest resources to the overall economy, for example through employment, values generated through processing and marketing of forest products, and energy, trade and investment in the forest sector. It also addresses the important forest function of hosting and protecting sites and landscapes of high cultural, spiritual or recreational value, and thus includes aspects of land tenure, indigenous and community management systems, and traditional knowledge.

7. Legal, policy and institutional framework

The theme includes the legal, policy and institutional arrangements necessary to support the above six themes, including participatory decision-making, governance and law enforcement, and monitoring and assessment of progress. It also involves broader societal aspects, including fair and equitable use of forest resources, scientific research and education, infrastructure arrangements to support the forest sector, transfer of technology, capacity-building, and public information and communication."

Source: FAO (2006: 4)

C&I systems were used to bring these elements of SFM in an operational (measurable) form. The general hierarchy of the criteria and indicators system is: principle – criterion – indicator – verifier. ITTO (2005, p. 8) defines: "A criterion is defined as an aspect of forest management that is considered important and by which sustainable forest management may be assessed. A criterion is accompanied by a set of related indicators and describes a state or situation which should be met to comply with sustainable forest management."

The ITTO scheme was revised and harmonized with a global set of criteria for SFM in international conferences on C&I in 2002 and 2004 (ITTO 2005, p. 8). These seven criteria are seen as essential elements of sustainable forest management (bullets are main groups of indicators), the order of the criteria does not indicate priority or relative importance (Box 2).

Box 2: ITTO global set of criteria and indicator groups for SFM

General legal, economic and institutional framework

Criterion 1: Enabling conditions for sustainable forest management

- Policy, legal and governance framework
- Economic framework
- Institutional framework
- Planning framework

Quantity, security and quality of forest resources

Criterion 2: Extent and condition of forests

Criterion 3: Forest ecosystem health

Goods and services provided by the forest

Criterion 4: Forest production

- Resource assessment
- Planning and control procedures
- Silvicultural and harvesting guidelines

Criterion 5: Biological diversity

- Ecosystem diversity
- Species diversity
- Genetic diversity
- Procedures for biodiversity conservation in production forests

Criterion 6: Soil and water protection

- Extent of protection
- Protective functions in production forests

Criterion 7: Economic, social and cultural aspects

- Socioeconomic aspects
- Cultural aspects
- Community and indigenous peoples' rights and participation

Source: (ITTO 2005, pp. 3, 8)

The "hard" C&I systems are not applied on a large scale yet. So the FAO reports in its Global Forest Resources Assessment 2010 about difficulties in assessing the area under SFM, because of lack of agreed definitions or of assessment methodologies. Finally a "soft" hands-on approach was chosen, in accordance to ITTO (2011, p. 20), including all forests which have fulfilled any of the following conditions (FAO 2010, p. 165):

- Certified or in process towards certification; fully developed, long-term (ten years or more) forest management plans being implemented effectively;
- Model forest units and information available on the quality of management;
- Community-based forest management units, with secure tenure and quality of management is of high standard;
- Protected areas with secure boundaries and management plan, considered to be well managed and not under significant threat from destructive agents.

2.6. Described factors and drivers for SFM

The following section summarizes factors and drives from literature sources. The factors identified were coded according the groups in Chapter 4 Results: [cpf] Choice to declare forest land as permanent forest land; [cms] Choice to give the FMU a mandate for SFM; [pas] FMU performance according to SFM mandate; [rf] Forest resource features; [uf] Forest user feature; [efc] External frame conditions.

An analysis of cases of formal degazetting forest reserves in Uganda by Mwavu and Witkowski (2008, p. 619) showed that the maintenance of the forest reserve for benefit both, development and conservation, require (1) strong institutions [cpf], which are able to withstand conflicts of interests and (2) the political will for a *sustainable* management of the forests/woodlands in the area [cms]. This case highlights the nested conditions by the stakeholders (legal owner, user and actors etc.): (1) the choice to maintain forest as *permanent* forest land, and (2) the choice to manage forests sustainably.

Pagdee et al. (2006) conducted a meta-study to identify success factors for community forests by counting the discussed success factors. While the idea of their study is similar to the one of the paper presented here, their understanding of “success” may be broader and with a strong orientation towards satisfaction of social needs as it is usually the case for community forests. Success was found to be manifested in several indicators (ibid. p. 40)*. As a result, 43 variables linked to success were identified (Padgee et al. 2006: 41-42) and grouped into nine major factors as shown in Figure 3.

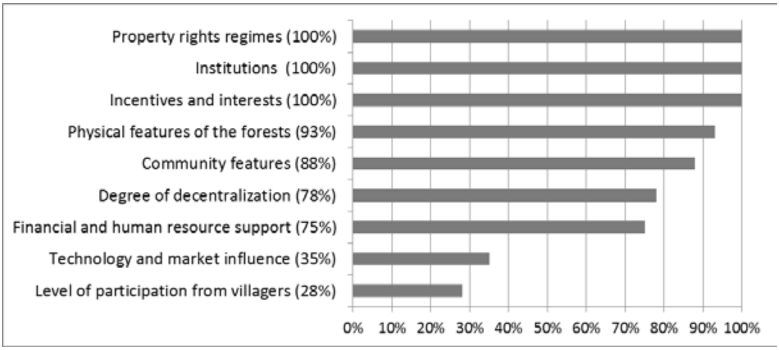

Figure 3: Factors repeatedly identified as important for successful SFM outcomes in the community forests

Ostrom identified attributes with relevance to successful collective action like community forestry. Internal attributes are community size and socioeconomic heterogeneity (Ostrom 1999:8-9). Attributes of common-pool resources and of users, which are conducive for self-governing associations are (ibid. p. 3-4: "Attributes of the Resource):

- R1. Feasible improvement: The resource is not at a point of deterioration such that it is useless to organise or so underutilised that little advantage results from organizing [rf]
- R2. Indicators: Reliable and valid information about the general condition of the resource is available at reasonable costs [efc]
- R3. Predictability: The availability of resource units is relatively predictable [rf]

* (1) Outcomes of ecological sustainability, including improvement of forest conditions (area, diversity, productivity, valuable species) and addressing environmental degradation by reforestation or soil erosion control; (2) social equity, referring to equitable sharing of the right to manage, equitable access and control of the forest resources, and responsibility for the forest resources; and (3) economic efficiency with meeting local needs, reducing conflicts between communities and authorities, control corruption, resolve mismanagement and overutilization and individual misuse of the forest.

- R4. Spatial extent: The resource is sufficiently small, given the transportation and communication technology in use, that users can develop accurate knowledge of external boundaries and internal microenvironments [rf], [cms]
- Attributes of the Users:
- A1. Salience: Users are dependent on the resource for a major portion of their livelihood or other variables of importance to them [uf]
- A2. Common understanding: Users have a shared image of the resource (attributes R1, 2, 3 and 4 above) and how their actions affect each other and the resource [uf]
- A3. Discount rate: Users have a sufficiently low discount rate in relation to future benefits to be achieved from the resource [uf]
- A4. Distribution of interests: Users with higher economic and political assets are similarly affected by a current pattern of use [uf]
- A5. Trust: Users trust each other to keep promises and relate to one another with reciprocity [uf]
- A6. Autonomy: Users are able to determine access and harvesting rules without external authorities countermanding them [uf], [cms]
- A7. Prior organisational experience: Users have learned at least minimal skills of organisation through participation in other local associations or learning about ways that neighbouring groups have organized [uf]"

A study with Canadian forest owners showed that they follow SFM not only by rational, but also because of deeper rooted values. The main motivations in their forestry related decisions are: (1) forest continuity (a strong affiliation to their forest land) [cpf], (2) benefit to the owner [rf], and (3) doing the "right thing" [uf], which refers to the ethic of conservation of the forest (Daniels et al. 2010, p. 49). While the second motivation (benefit to the owner) is of clear economic nature, the two others belong to non-economic, cultural spheres: traditions and value systems as well as to the personal characters of following these traditions and respecting these values. Beyond the economic benefits and securities the latter are important sources for motivation to stand for and to limit oneself for SFM.

For group or community owned forests a set of working hypotheses was compiled by the IFRI*[*] team under the lead of Elinore Ostrom (IFRI 2007, pp. I-5), referring to positive factors in successfully resulting sustainable forest systems (since some of these hypotheses describe rather the results than structures there may be more than the indicated relations to the factor groups):

- "the expected value of long-term use of a forest exceeds the expected cost of managing the forest; [rf]
- local forest users participate in and have continuing authority to design the institutions that govern the use of a forest system; [cms]
- the individuals most affected by the rules that govern the day-to-day uses of a forest system are included in the group that can modify these rules; [cms]
- the institutions that govern a forest system minimize opportunities for free riding, rent seeking, asymmetric information, and corruption through effective procedures for monitoring the behavior of forest users and officials; [cms]
- forest users who violate rules governing the day-to-day uses of a forest system are likely to receive graduated sanctions from other users, from officials accountable to these users, or both; [cms]
- rapid access is available to low-cost arenas for resolving conflict between users or between users and their officials; [efc]
- monitoring, sanctioning, conflict resolution, and governance activities are organized in multiple layers of nested enterprises; and [cms]
- the institutions that govern a forest system have been stable for a long period and are known and understood by forest users. [cpf]" (IFRI 2007, pp. I-5)

[*] International Forestry Resources and Institutions (IFRI) Research Program

Regarding Mexico it was found, that in areas without active colonization fronts (meaning areas which are not recently inhabited) community managed forests presented lower and less variable annual deforestation rates than the protected forest areas (Bray et al. 2008; Porter-Bolland et al. 2012, p. 6).

3. Conceptual framework

The maintenance of a certain forest as *permanent* forest land is considered as a precondition for the stakeholders' choice to give a mandate to implement SFM for these forests. In cases where the two choices are taken in favor for both to maintain *permanent* forest land and to *implement* SFM, the FMU can receive the full support to perform SFM successfully. In such cases the performance of the unit and the drivers for its successful SFM can be studied. In competing situations, where there is a dispute by key stakeholders[*] about the destination for forest land, even a motivated FMU may struggle to perform SFM in the long run. The choice to maintain permanent forest land and to implement SFM for a certain forest area is part of governance. Forest governance is understood as the sum of stakeholder interactions which are leading to the forest owner's decision for utilization and management of the forest land. This is not necessarily SFM. It may result in either imbalanced objectives like total conservation, in "mining" forest resources, in overutilization and degradation resulting in destabilizing and fragmenting the forest. In the case of a choice for SFM, the mandate and responsibility for SFM will be given to a unit implementing the forest management (FMU). If the owner is a natural person it can also be done by him-/herself. So, the owner and key stakeholders are determining the management objectives, and the management unit is tasked to achieve the given objectives. The concept can be illustrated with the observation that

[*] Key stakeholders are stakeholder with veto power.

people living in tropical forests as smallholder or dweller are often anticipated as a FMU which is interested in performing SFM (e.g. in farm forestry[*] or community forestry[†]). In a closer look their mainstream forest management is a de facto a medium term conversion of forest land into farm land. In studying such cases the analysis should clearly elaborate the objectives of the stakeholders, and based on this mandates the performance of the FMU.

To analyze the performance of a FMU it has to be measured in relevance to the determined management objectives. Only in cases where a clear choice for permanent forest land and a mandate for SFM are given, the FMU is able and is in charge to perform SFM. Conversion of forest land in other land uses by key stakeholder as well as illegal use and use *beyond* the mandate and/or control of the forest management unit cannot be claimed as a failure of the FMU in performing SFM. Only a conversion of forest land in other land use as well as illegal use and use *under* the mandate and/or control of the forest management unit should be claimed as a failure of the FMU in their SFM performance (Fig. 4).

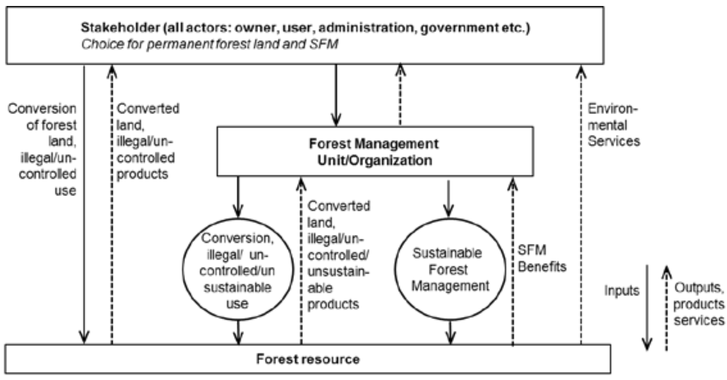

Figure 4: Conceptual framework for the assessment of SFM factors

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[*] E.g in the lowland of Bolivia, as orally communicated from researchers doing field work there.
[†] Author's observation in talks with members and stakeholders of emerging community forests in Otjozondjupa Region, Namibia.

In conclusion of the considerations above an assessment of factors and drivers for best practice SFM should be done in a nested approach, on two distinct levels: (1) The 'mandate' including the management goals and objectives, as a result of governance processes, analyzed with regard to all relevant actors and their policies. (2) Performance of the FMU under the given mandate. The two levels may be interwoven and not easily separated because the FMU acts as one of the stakeholders in the governance process around the mandate.

4. Results

The factors for SFM which are identified in the literature review were grouped accordingly to the decision making groups (user, FMU, key stakeholder) as it is illustrated in the theoretical framework (Fig. 4). The groups of factors listed below were identified. The code in squared brackets refers to the single factors described in the literature review.

- Choice to declare forest land as permanent forest land [cpf]
- Choice to give the FMU a mandate for SFM [cms]
- FMU performance according to SFM mandate [pas]
- Forest resource features [rf]
- Forest user features [uf]
- External frame conditions [efc]

A graphic arrangement of the factor-groups shows them as "pillars" for "best practice SFM". It reveals that many factors are not under direct control by the FMU (Fig. 5). The arrangement simplifies the interdependence of factors, but nevertheless, it indicates that a FMU alone can hardly control a successful SFM implementation; it needs the support of users and stakeholders as well as supporting frame conditions.

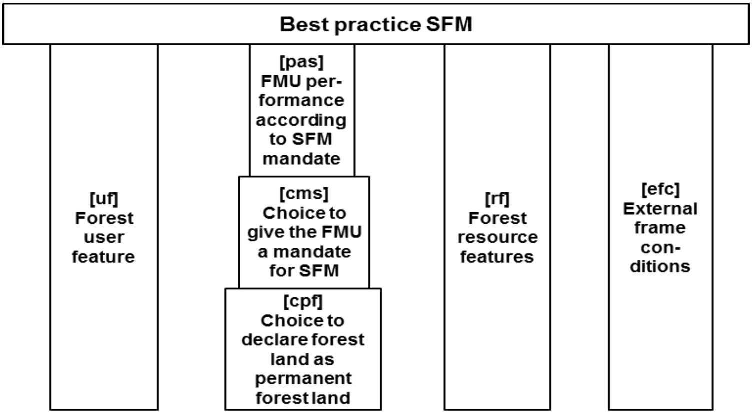

Figure 5: Factors for best practice SFM

5. Discussion

Factors which support SFM in a positive sense were identified from literature and grouped according to the decision making groups. From all SFM supporting factors found, the forest management unit (FMU) controls only one group of factors fully [pas], the others are determined by stakeholders, by the features of today's forest resource, by the forest users and/ or by frame conditions. A FMU which has got a mandate for SFM but is not fully supported by the stakeholders is hardly able to perform SFM. This insight shifts the initial focus from positive factors to controllable factors, and addresses the crucial responsibility of key stakeholders for sustainable choices and mandates.

Several studies and publications deal with deforestation. Is it enough to use the absence of deforestation as indicator for successful SFM? The difficulties reported by FAO (2010) in determining "SFM" to identify corresponding forest areas (see Section 3.2) is quite sobering and indicates the challenges in performing the SFM concept. Despite the fact that nearly 150 countries, containing 97.5 % of the global forest area, participating voluntarily in C&I processes (Wijewardana

2008, p. 115) – there is still a long way to go from the current C&I harmonization on international level to effective, standard SFM monitoring systems on the FMU level. This highlights the need for research on measurable and meaningful SFM indicators. For an organization's management it is not enough to measure SFM indicators; FMUs should become a quality management system as the usual standard. Obligatory part for these quality management systems have to be a tool facilitating the agreement of the key forest stakeholders on objectives and trade-offs between competing objectives as well as their rational measurement and holistic, meaningful interpretation (Wijewardana 2008, p. 119). Combined with an adaptive management approach such efforts and agreements can be made operational and put in practice in a flexible way.

Factors and drivers for SFM could be studied in a comparative analysis design and in a nested approach. A sample of FMUs practicing SFM successfully should be compared with one of obviously not performing SFM. Also multiple organizational models of FMUs should be considered (e.g. smallholder forestry, community forestry, large commercial forest enterprise etc.). An operational set of dependent variables has to be identified, like the success indicators from Pagdee at al. (2006; see Footnote 5). The different factors for SFM serve as independent variables. A regression analysis serves to assess which of the factors being the significant ones, functioning really as "drivers" for SFM.

To approach the problem in an analytical way the theoretical framework in Chapter 4 provides a structure to reduce the complexity of the problem with a nested approach. Supporters of SFM may assume that with a FMU in place the stakeholders automatically have given a full mandate for SFM, and based on this their focus of interventions is on technical inputs (e.g. forest inventory, value addition through milling, silviculture etc.), FMU capacity building (training of forest managers, forest management committees, rangers etc.) or organizational development (creating decision making bodies etc.). If the assumption about the given mandate was not correct, the intervention is likely not to yield SFM. The results from Pagdee's et al. (2006; see Fig. 3) meta-study support the statement, financial and human resource support were only in 75% of the studies seen as success factor. A more differentiated analysis in the sense of the nested approach could be used to improve the design and impact of SFM supporting interventions.

SFM is connected with higher transaction cost, especially in common pool situations. As long as forests provide enough products (including commercialized services) and nonmarket benefits for the users to pay off both the direct forest operation cost and the transaction cost, SFM is a viable option. This is one of the principles Ostrom (1990) identified for the successful management of common pool resources. In the other cases, where the produced products and services are not enough and/or do not have a market; external support would be required to run SFM efficiently. External support could come from the public owner as service (expertise, labor, products), or as subsidy payment, it could also come from none-governmental groups or institutions (community, beneficiaries and interest groups) on different levels and in various models.

Coming back to the research questions.

- The answer of the first one (How is the best practice of SFM determined?) reveals the many difficulties to transfer the complexity of SFM into simple, measurable indicators.
- The second question (What are factors and drivers for such best practice SFM) has been answered by listing and grouping several factors found in the literature review (Fig. 5).
- The final question (how are they to identify?) has been narrowed by structuring the entities controlling factors in a nested approach (Fig. 4). To identify the real "drivers" for a specific case, research on factors with regression analysis should be used.

Finally, there are pessimistic forecasts about the future of natural forests in the tropics. The natural forests are considered as being not profitable enough, hindering land uses with higher financial returns and are highly attractive to liquidize for short term profits. Often there is no lobby for them, so some will become conservation area; others are likely to be mined and converted. It is expected that planted forests will be extended at the cost of natural forest, from smallholder scale to large industrial schemes (Bird 2011). If this becomes true the complexity of SFM will become less and easier to handle – but for the high price of impoverished forests.

References

AGFE-AGLP (1982) Leitfaden zur Kartierung der Schutz- und Erholungsfunktionen des Waldes (Waldfunktionenkartierung) WFK, 2nd edn. Sauerländer, Frankfurt a.M.

Auch, Eckhard; Pretzsch, Jürgen; Uibrig, Holm (2014): Organizational Changes in Forest Management. In Jürgen Pretzsch, Dietrich Darr, Holm Uibrig, Eckhard Auch (Eds.): Forests and Rural Development, vol. 9: Springer Berlin Heidelberg (Tropical Forestry), pp. 111-144. Available online at http://dx.doi.org/10.1007/978-3-642-41404-6_5.

Oxford Dictionaries (undated) Available online at http://oxforddictionaries.com/definition/english/, checked on 14/02/2013.

Baland, Jean-Marie; Platteau, Jean-Philippe (1999) The Ambiguous Impact of Inequality on Local Resource Management. In World Development 27 (5), pp. 773–788.

Bird, Neil (2011): Where does the future lie for forestry? Edited by Overseas Development Institute (ODI). London. Available online at http://www.odi.org.uk/opinion/5681-does-future-lie-forestry, checked on 14/02/2013.

Bray, David Barton; Duran, Elvira; Ramos, Victor Hugo; Mas, Jean-Francois; Velazquez, Alejandro; McNab, Roan Balas et al. (2008) Tropical deforestation, community forests, and protected areas in the Maya Forest 13 (2), p. 56. Available online at http://lib.icimod.org/record/13523/files/4243.pdf.

Brundtland, Gro Harlem (Ed.) (1987) Our common future. World Commission on Environment and Development (WCED). Oxford: Oxford University Press.

Carlowitz, Hannß Carl von (1713) Sylvicultura oeconomica, oder haußwirthliche Nachricht und Naturgemäße Anweisung zur Wilden Baum-Zucht. Reprint of 2nd edition, 2009. Remagen-Oberwinter, Germany.

Daniels, Steven E.; Kilgore, Michael A.; Jacobson, Michael G.; Greene, John L.; Straka, Thomas J. (2010) Examining the compatibility between forestry incentive programs in the US and the practice of sustainable forest management. In Forests 1 (1), pp. 49–64. Available online at http://www.mdpi.com/1999-4907/1/1/49/htm, checked on 23/02/2013.

FAO (1993) FESLM: An international framework for evaluating sustainable land management. Edited by Food and Agriculture Organization of the United Nations (FAO). Rome (World soil resources reports, 73). Available online at http://www.fao.org/docrep/T1079E/T1079E00.htm, checked on 21/02/2013.

FAO (2006) Global forest resources assessment 2005 - progress towards sustainable forest management. FAO Forestry Paper 147. Rome: Food and Agriculture Organization of the United Nations (FAO).

FAO (2010) Global Forest Resources Assessment 2010. Main report. Rome: Food and Agriculture Organization of the United Nations (FAO). (FAO Forestry Paper, 163). Available online at http://www.fao.org/docrep/013/i1757e/i1757e.pdf.

FAO (2011) 2011: State of the World's Forests. Rome: Food and Agriculture Organization of the United Nations (FAO).

Galante, Michael Victor; Dutschke, Michael; Patenaude, Genevieve; Vickers, Ben (2012): Climate Change Mitigation Through Reduced-Impact Logging and the Hierarchy of Production Forest Management. In Forests 3 (4), pp. 59–74. Available online at http://www.mdpi.com/1999-4907/3/1/59/pdf, checked on 23/02/2013.

IFRI (2007) Field Manual. Version 13, revised Aug. 2008. Edited by Population and Environmental Change Indiana University Center for the Study of Institutions. International Forestry Resources and Institutions (IFRI) Research Program.

ITTO (2005) Revised ITTO criteria and indicators for sustainable management of tropical forests including reporting format. Yokohama, Japan: International Tropical Timber Organization (ITTO Policy Development Series, 15). Available online at http://www.itto.int/direct/topics/topics_pdf_download/topics_id=9630000&no=1&disp=inline.

ITTO (2011): Status of tropical forest management 2011. Yokohama (ITTO Technical Series, 418). Available online at http://www.itto.int/en/sfm/.

Kotwal, P. C.; Omprakash, M. D.; Gairola, Sanjay; Dugaya, D. (2008) Ecological indicators: Imperative to sustainable forest management. In Ecological Indicators 8 (1), pp. 104–107. Available online at http://www.sciencedirect.com/science/article/pii/S1470160X07000210.

McDonald, G. T.; Lane, M. B. (2004): Converging global indicators for sustainable forest management. In Forest Policy and Economics 6 (1), pp. 63–70. DOI: 10.1016/S1389-9341(02)00101-6.

Monserud, Robert A. (2003) Evaluating forest models in a sustainable forest management context. In Forest Biometry, Modelling and Information Sciences 1, pp. 35–47. Available online at http://cms1.gre.ac.uk/conferences/iufro/fbmis/A/3_1_MonserudR_1.pdf, checked on 23/02/2013.

Mwavu, E. N.; Witkowski, E. T. F. (2008) Land-use and cover changes (1988-2002) around Budongo forest reserve, NW Uganda: implications for forest and woodland sustainability (6). Available online at http://onlinelibrary.wiley.com/store/10.1002/ldr.869/asset/869_ftp.pdf?v=1&t=hdirlmuy&s=55c9d68c1298344c44fd8a6f5066cdebf53614cc, checked on 23/02/2013.

Ostrom Elinor (1990) Governing the Commons. The evolution of institutions for collective action, Cambridge University Press, Cambridge

Ostrom, Elinor (1999) Self-governance and forest resources. Bogor, Indonesia (CIFOR Occasional Paper). Available online at http:/www.cifor.org/online-library/browse/view-publication/publication/536.html, checked on 10/10/2013.

Pagdee, Adcharaporn; Kim, Yeon-Su; Daugherty, P.J (2006) What makes community forestry successful: A meta-study from community forests throughout the world. In: Society and Natural Resources 19, S. 33–52..

Porter-Bolland, Luciana; Ellis, Edward A.; Guariguata, Manuel R.; Ruiz-Mallén, Isabel; Negrete-Yankelevich, Simoneta; Reyes-García, Victoria (2012) Community managed forests and forest protected areas: An assessment of their conservation effectiveness across the tropics. In Forest Ecology and Management 268 (0), pp. 6–17. Available online at http://www.sciencedirect.com/science/article/pii/S0378112711003215.

UNDP (2011) Keeping Track of our Changing Environment: from Rio to Rio+20 (1992–2012). Nairobi.

UNEP (2012) Geo 5 - global environment outlook. Environment for the future we want. Available online at http://www.unep.org/geo/pdfs/geo5/GEO5_report_full_en.pdf, checked on 15/02/2013.

Wijewardana, Don (2008): Criteria and indicators for sustainable forest management: The road travelled and the way ahead. In Evaluating sustainable forest management. An international collection of empirical and applied research 8 (2), pp. 115–122. DOI: 10.1016/j.ecolind.2006.11.003.

Innovation System Analysis for Sustainable Management of Natural Resources – Some Conceptual and Methodological Remarks

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Abstract

Despite considerable efforts aimed at developing innovative technologies for natural resource management that are socio-economically, environmentally and culturally adapted to the needs of African farmers, average adoption rates of such technologies often remain disappointing. Linked to the various attempts to explain this adoption gap, it has been recognized that the traditional 'Transfer of Technology' paradigm is not suited to conceive the generation, diffusion and adoption of innovations by farmers. Rather it has become increasingly clear that innovation emerges from the interaction of various stakeholders and therefore requires alternative ways of organizing.

The paper introduces major concepts and propositions of the innovation systems perspective and elaborates on contemporary methodological approaches available to study these systems. In particular, it presents innovation histories as one method to advance the understanding of the dynamics of innovation and adoption. Building on key insights generated by recent research in this area, the paper concludes with a reflection on required policy interventions in innovation systems.

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1. Introduction

Considerable efforts have been made since the Green Revolution to develop innovative farm management technologies that are socio-economically, environmentally and culturally adapted to the needs of farmers (e.g. Böhringer 2001, Desta et al. 2005).In spite of considerable past efforts to disseminate these technologies, adoption has often lagged behind expectations (e.g. Belay 2003; Gautam 2000; Weir and Knight 2000), in particular so insub-Saharan Africa (SSA). For example, adoption rates for modern maize varieties have been determined to be 17% of total area harvested in SSA only, compared to 57% in Latin America and the Caribbean and 90% in East and Southeast Asia and the Pacific (Gollin and Morris 2005). Likewise, the adoption rates for advanced irrigation methods (i.e., drip and sprinkler irrigation) reach 30% of the total irrigated area in SSA only, compared to 53% in North America, 61% in Central and East Europe and 66% in Western Europe (Sauer et al. 2010). The apparent failure of past extension efforts has been linked to the inappropriateness of the "transfer of technology paradigm", which conceives a linear research-development chain and postulates a clear division of tasks between the variousstakeholders engaged in technology generation and application (Leeuwis and van Ban 2004; Röling 1995).

2. Innovation systems as the contemporary perspective on innovation generation and dissemination

In contemporary rural extension science, system models of innovation have superseded linear models of innovation (Röling and Engel 1991). The concept denotes the set of stakeholders involvedin the generation, transformation, dissemination, and utilization of relevant knowledgeand information, and their links and interactions (Röling 1990, cited in Rölingand Engel 1991). Innovation systems grant conditions conducive for innovationgeneration and dissemination by fostering cooperation and managing conflictamong stakeholders; providing a platform for learning and experimentation; reducinguncertainty; developing an infrastructure for strategy and vision development;and creating incentives (Kubeczko and Rametsteiner 2002; Rametsteiner 2010). Figure 1 illustrates the essence of both concepts.

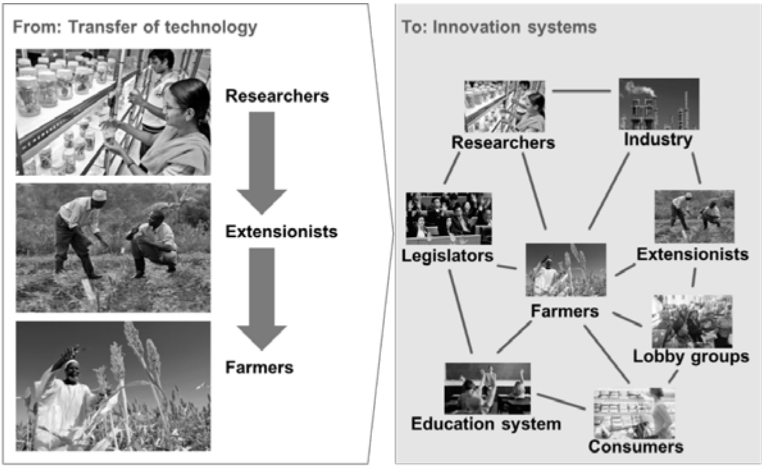


Figure 1: The Transfer-of-technology paradigm has been superseded by system models of innovation

Innovations, according to the innovation systems perspective, are created in aco-evolutionary process that is seen as both an individual and a collective actinvolving multiple interactions between components of farming systems, supply chains and economic systems, policy environments, and societal systems, and combining technological, social, economic and institutional change(Klerkx et al. 2012, Edquist 2001). Innovations, furthermore, are seen as dynamic and characterized by constant modifications and adaptations, which may lead to their further development and progressive advancement or to their abolishment and replacement by better technologies.

Innovation systems can be defined and studied at various levels (see Figure 2). National innovation systems aim to describe and analyze the innovation activities at the level of the entire national economy, whilesectoral innovation systems focus on specific economic sectors.For example, the Agricultural Innovation System (AIS) describes the frame conditions and stakeholders that are involved in the creation and dissemination of agricultural technologies. Technological innovation systems focus on a unique technology and its users, stakeholders and institutions and cut across sectoral and geographical levels (Hekkert and Negro 2010).

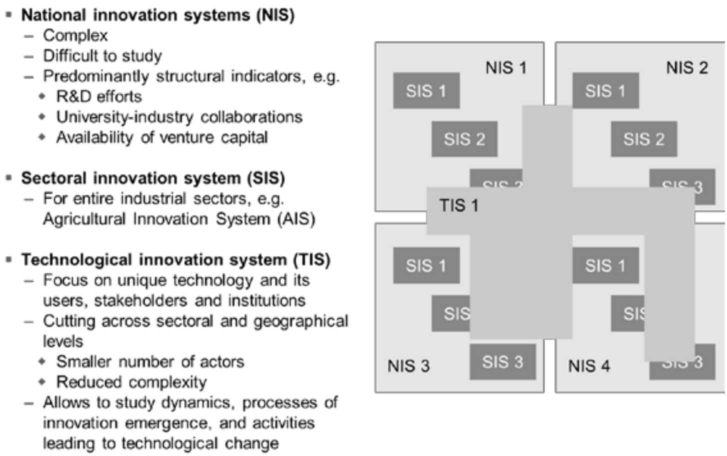


Figure 2: Types and levels of innovation systems

The primary objective of innovation systems is to contribute to the development and diffusion of innovations. The literature describes 7 detailedfunctions of innovation systems (Hekkert et al. 2007; Hekkert and Negro 2010), which are displayed in Figure 3.

Figure 3: Functions of innovation systems

Klerkx et al. (2012) and Weber and Rohracher (2012) define a number of key enablers and disablers for innovation system performance (Figure 4). For example, informational asymmetries as one form of market failure negatively impact the performance of the innovation system, as they typically increase the uncertainty about outcomes and, combined with the short time horizon of private investors, lead to an undersupply of funding for R&D activities. Furthermore, the public good character of knowledge and leakage of knowledge may lead to socially sub-optimal investment in (basic) R&D.

Key enablers

Learning
- Within and between firms and organizations
- Covering multiple dimensions, i.e. technology, markets, policy etc.

Capability building
- Strengthening capabilities to innovate
- Individual and collective level

Coordination
- Demand and supply-driven science and technology
- Innovation agents focusing on complex and dynamic interactions

Dissemination
- Knowledge dissemination networks
- Dissemination of tacit and codified knowledge

Governance
- Decentralized management of innovation processes

Key disablers

Infrastructure failure
- Absence of required physical infrastructure
- Lack of required investments

Institutional failure
- Laws, regulations, formalized rules
- Unwritten rules, norms, values, culture

Network failure
- Actors locked into too cohesive relationships
- Actors not well connected to external stakeholders

Capabilities failure
- Stakeholders unable to adapt to and manage new technology and organizational innovations

Market failures
- Informational asymmetries and knowledge spillover
- External effects and over-exploitation of commons

Transformational system failures
- Directionality and demand articulation failure
- Policy coordination failure
- Reflexivity failure

Figure 4: Keyenab-lers and disablers of innova-tion system performance

3. Innovation systems analysis

Klerkx et al. (2012) and Spielman et al. (2009) describe a number of methodological approaches for the study of innovation systems (Figure 5).

Institutional analysis	Social network analysis	Functional analysis	Game theo-retic analysis	Benchmark analysis	Innovation histories
▪ Institutional enablers and constraints of innovation systems per-formance ▪ Structures and mecha-nisms that lead to the relevant decisions and results	▪ Linkages between stakeholders and their re-lative position to each other ▪ Visualization of formal and informal so-cial relation-ships and information flows	▪ Description to which extent all innovation system functions are properly performed	▪ Modeling of spontaneous processes of social self-organization ▪ Focus on interdepen-dencies bet-ween stake-holders	▪ Linking innovation system per-formance to hard system indicators, such as number of patents, R&D expenditures, etc. ▪ Comparative analysis	▪ Documenta-tion of inno-vation pro-cess and timeline ▪ Focus on sequences of events and activities to create insight into the dynamics of innovation

Figure 5: Methodo-logical approaches for the study of innovation systems

As a qualitative and often longitudinal research approach, innovation histories can yield significant insight into the emergence and evolution of innovation projects in firms and enterprise networks and the functioning of innovation systems more generally. The research approach is well suited to study innovations at the levels which are not directly amenable for quantitative studies, e.g.the TIS. Hekkert and Negro (2010) describe in detail the sequence of steps that is required when studying innovation systems using innovation histories (Figure 6).

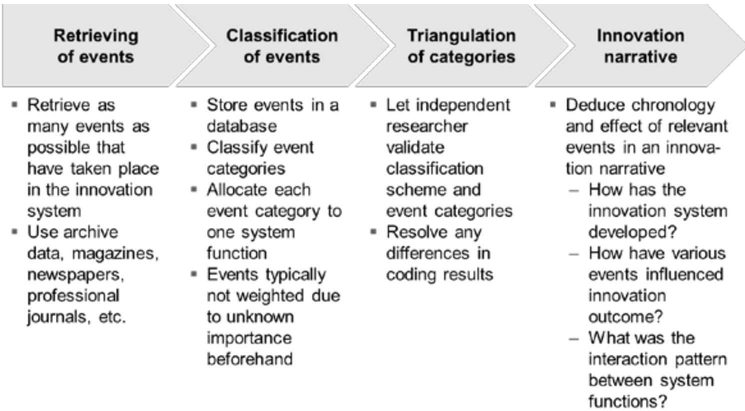


Figure 6: Conceptual steps for studying innovation histories

A major insight from their study is that very often, a virtuous cycle of reinforcing positive events leads to the diffusion of a new technology (Figure 7). Innovation istypically created as a consequence of the guidance, resource mobilization and knowledge development function of the innovation system (Hekkert and Negro 2010). Thisfinding clearly contradicts the linear model where innovation processes typically are believed to start with either technology push or market demand. While innovation histories typically create insights at the level of the individual case and can be used to describe the functioning of one particular innovation system and construct hypotheses around reoccurring event sequences and interaction patterns, generalization of results can be achieved through time series analysis methods and correlation analysis between different functions over time and in various innovation systems (Hekkert and Negro 2010).

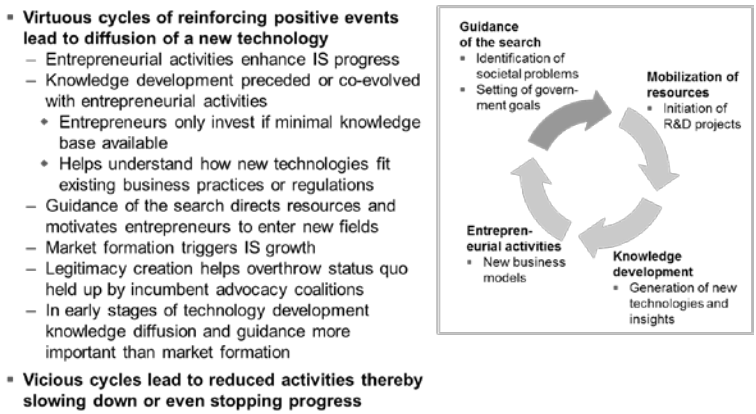


Figure 7: Major insights from innovation histories

4. Interventions to improve the functioning of innovation systems

Bergek et al. (2008) describe normative innovation system analysis as the attempt of policy makers to induce a “desired” functional pattern in innovation systems by identifying and addressing mechanisms at the systems level that either induce or block a desirable functional pattern. According to Klerkx et al. (2012), these interventions can take place at the level of the support system or directly at the network level of the innovation system (Figure 8).

Support system-level interventions

- Structural changes to optimize functioning of the innovation system, e.g.
  - Realign visions and mandates of stakeholders
  - Enhance innovative capabilities by investments in training
  - Facilitate flow of information and technology by modernizing extension systems
  - Induce change in organizational cultures by introducing demand-driven research
  - Create conducive policy environment by increasing influence of the sector on policies
- Existing structures typically well support incremental change, but not radical innovation

Network-level interventions

- Stimulate formation of innovation networks through platforms, coalitions, partnerships
- Support creation of linkages/ partnerships and stimulate learning
  - Dedicated innovation brokers
    - Actors explicitly dedicated as systemic intermediary
    - Build linkages and facilitate multi-actor interaction
    - Specialized actors or established organizations
  - Reflexive monitoring
    - Participatory M&E
    - Network actors learn to develop solutions jointly

Figure 8: Interventions in innovation systems

While innovation policy is typically still dominated by financial instruments, interventionsthat directly address the structure and efficiency of the innovation system should be regarded as at least equally important in promoting the generation and diffusion of innovations. Examples for such interventions comprise initiating discourse, alignment and consensus among system stakeholders, improving accessibility for all relevant stakeholders or stimulate demand articulation, strategy, and vision development (Hekkert et al. 2007).

References

Belay, K. (2003) Agricultural Extension in Ethiopia: The Case of Participatory Demonstration and Training Extension System. Journal of Social Development in Africa, 18(1), pp. 4984.

Bergek A, Jacobsson S, Carlsson B, Lindmark S, Rickne A (2008): Analyzing the functional dynamics of technological innovation systems: A scheme of analysis. Research Policy 37(3): 407–429

Böhringer, A. 2001: Facilitating the wider use of agroforestry for development in southern Africa. Development in Practice 11(4):434–448.

Desta, L.; Carucci, V.; Wendem-Agenehu, A., et al. (eds.) 2005: Community based participatory watershed development: A guideline. 2 volumes. Addis Ababa (1).

Edquist C (2001): Innovation Systems and Innovation Policy: the state of the art. in Invited Paper for DRUID's Nelson-Winter Conference, Aalborg, Denmark

Gautam, M. (2000) Agricultural Extension: The Kenya Experience. Washington, DC: The World Bank.

Gollin D, Morris M (2005): Technology adoption in intensive post-green revolution systems. American Journal of Agricultural Economics 87(5): 1310-1316.

Hekkert MP, Negro SO (2010): Functions of innovation systems as a framework to understand sustainable technological change: empirical evidence for earlier claims. ISU Working Paper 08.10 Copernicus Institute for Sustainable Development and Innovation, Utrecht University.

Hekkert MP, Suurs RAA, Negro SO, Kuhlmann S, Smits REHM (2007): Functions of innovation systems: A new approach for analysing technological change. Technological Forecasting and Social Change 74: 413–432

Klerkx L, van Mierlo B, Leeuwis C (2012): Evolution of systems approaches to agricultural innovation: concepts, analysis and interventions. In: Darnhofer I, Gibbon D, Dedieu B (eds.): Farming Systems Research into the 21st Century: The New Dynamic. Dordrecht: Springer

Kubeczko K, Rametsteiner E (2002) Innovation and entrepreneurship – a new topic for forestrelated research. EFI-INNOFORCE discussion paper I and IFSPE discussion paper P/2002-1,University of Agricultural Sciences, Vienna

Leeuwis C, van den Ban AW (2004) Communication for rural innovation. Rethinking agriculturalextension, 3rd edn. Blackwell Science, Oxford

Rametsteiner E (2010) Integrating innovation and development policies for the forest sector: anintroduction. In: Rametsteiner E, Weiss G, Ollonqvist P, Slee B (eds) Policy integration andcoordination. The case of innovation and the forest sector in Europe. COST Action E51.Publications Office of the European Union, Luxembourg, pp 1–10

Röling NG (1995) What to think of extension? A comparison of three models of extensionpractice.AERDD bulletin. University of Reading, Reading

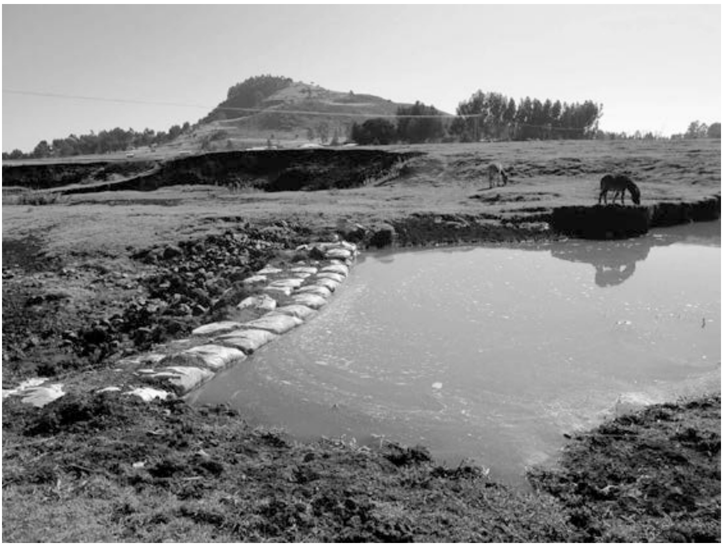
Röling NG, Engel PGH (1991) The development of the concept of agricultural knowledgeinformation systems (AKIS): implications for extension. In: Rivera WM (ed) Agriculturalextension. Worldwide institutional evolution and forces for change. Elsevier, Amsterdam,pp 125–137

Sauer T, Havlík P, Schneider UA, Schmid E, Kindermann G, Obersteiner M (2010): Agriculture and resource availability in a changing world: The role of irrigation. Water Resources Research 46 (W06503)

Spielman DJ, Ekboir J, Davis K (2009): The art and science of innovation systems inquiry: Applications to Sub-Saharan African agriculture. Technology in Society 31 (2009) 399–405

Weber KM, Rohracher H (2012): Legitimizing research, technology and innovation policies for transformative change Combining insights from innovation systems and multi-level perspective in a comprehensive ‘failures’ framework. Research Policy 41 (2012): 1037–1047

Weir, S.; Knight, J. (2000) Adoption and Diffusion of Agricultural Innovations in Ethiopia: The Role of Education. Working Paper 20005, University of Oxford, Centre for the Study of African Economies, Oxford.



Land Use Change / Environmental Services from Forests

Drivers of Tropical Deforestation: A Review

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Abstract

Deforestation, especially in the tropics, continues to occur at alarming rates. These pose a major threat to the continued availability of goods and services that support livelihoods of a huge proportion of the human population, especially the poor in developing countries. Despite numerous interventions by governmental and non-governmental entities to combat deforestation, forest cover continues to decline. Combating deforestation and forest degradation is premised on addressing its drivers. Therefore, the ineffectiveness of existing interventions suggests inadequate and or incomplete understanding of the drivers of deforestation and forest degradation. Since a considerable amount of research about drivers of deforestation has been conducted, it is imperative that such research studies be reviewed so as to establish the current state of knowledge on the subject. Additionally, reviewing existing research studies helps identify trends, new perspectives, gaps and or conflicts. Hence, this narrative review that compares and summarises selected studies to further knowledge about deforestation.

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1. Introduction

Deforestation continues to affect the humid tropical forests of Latin America, Africa and Asia (Tangley, 1986; Bawa and Dayanandan, 1997; Nagendra, 2007). Some of the consequences of deforestation include soil erosion, drought, flooding, water quality degradation, declining agricultural productivity and ultimately greater poverty for rural inhabitants of tropical nations in addition to species extinction (Tangley, 1986). Deforestation will also lead to loss of globally important carbon sinks that currently sequester carbon dioxide from the atmosphere thus impacting climate stability (Stephens *et al.,* 2007). Addressing deforestation is especially important as it impacts the lives and livelihoods of millions of forest-dependent inhabitants around the world (Tangley, 1986; Nagendra, 2007). Many interventions aimed at either conserving or sustainably managing forest resources, ranging from government-owned protected areas to private conservation through parks and community reserves, have been implemented over time (Nagendra, 2007). Despite the interventions, deforestation continues. Combating deforestation is premised on addressing its drivers. Therefore, the ineffectiveness of existing interventions suggests inadequate and or incomplete understanding of the drivers of deforestation. Since a considerable amount of research about drivers of deforestation has been conducted, it is imperative that such research studies be reviewed so as to establish the current state of knowledge on the subject. Additionally, reviewing existing research studies helps identify trends, new perspectives, gaps and or conflicts. Hence, this literature review that compares and summarises selected studies thus broadening the understanding of drivers of deforestation.

2. Methods

This study was aimed at comparing and summarizing drivers of deforestation in the tropics. The focus was on published studies which were selected from various sources including online databases, libraries and Google searches. The search terms included: (i) Land use land cover change drivers, (ii) Drivers of deforestation, and (iii) Causes of deforestation. Only studies that focused on the tropics and were addressing land use change were selected for further consideration. The total number of studies screened was 18 Out of which 10 were included. The studies were reviewed only to determine the drivers of deforestation with the intention of categorizing them based on similarities to create a more general picture of the drivers of deforestation in the tropics as depicted by several studies.

3. Results

(i) Drivers of deforestation in the tropics

Several studies have examined deforestation and its causes. Bawa and Dayanandan (1997) examined the correlations between tropical deforestation and socioeconomic variables across sites in Latin America, Africa and Asia. They found deforestation to be positively correlated with population density, per capita external debt, cattle density, cropland area/total land area, land in other use/total land area, forest products (fuelwood, charcoal, round wood and panel products) extracted per unit forest area, and per capita energy consumption. In Latin America, proportion of crop-land had the greatest effect followed by per capita external debt and then population density. This was in comparison with population density, per capita external debt and proportion of crop-land in Africa and proportion of crop-land, per capita external debt and population density in Asia. Population density, per capita external debt, proportion of crop-land area, fuel-wood and charcoal production, and per capita traditional fuel consumption accounted for 42 % (all tropical countries), 33 % (Africa), 96 % (Asia) and 48 % (Latin America) of the variance in rate of deforestation. These results, in addition to revealing some causes of deforestation, also highlight the variability of causes of deforestation with geographical location.

Place and Otsuka (2000) determined factors driving tree cover change around Lake Kyoga in Uganda in which they found the important factors to be population pressure, market access and land tenure. Utilizing International Forestry Resources and Institutions (IFRI) protocols (Nagendra, 2007), Uganda Forestry Resources and Institutions Center (UFRIC) at Makerere University has created a dataset about forests and their users. Namaalwa (2008) analyzed the UFRIC dataset and concluded that establishing appropriate forms of tenure to delineate boundaries and limit exploitation is an important step toward achieving forest sustainability. Vogt and others (2006) also found land tenure to have significant influence on land-cover changes in Uganda.

Geist and Lambin (2002) explored proximate causes and underlying driving forces of tropical deforestation from local-scale case studies. Proximate causes of deforestation included agricultural expansion, wood extraction and infrastructure extension. These were driven by a number of underlying factors which included: (i) economic factors (e.g., commercialization and development of timber markets; market failures; product price increases, especially of cash crops; low domestic costs for land, labor, fuel and timber; the requirement to generate foreign exchange earnings at the national level; and frontier colonization in the form of either poverty- or capital-driven deforestation), (ii) institutional factors (e.g., formal pro-deforestation measures such as policies on land-use and economic development related to colonization, transportation or subsidies for land-based activities; land tenure arrangements and policy failures such as corruption and mismanagement of the forestry sector; insecure ownership, quasi-open access conditions, maladjusted customary rights and legalization of land titles), (iii) technological factors (e.g., agro-technological change and poor technological applications in the wood sector), (iv) cultural and sociopolitical causes (e.g., attitudes of public unconcerned about forest environments), and (v) demographic factors (e.g., in-migration of colonizing settlers into sparsely populated forest areas resulting into higher population densities). In agreement with Bawa and Dayanandan (1997), they also found the causes of deforestation to vary with geographic location. They thus recommended that detailed understanding of the complex set of proximate causes and underlying driving forces affecting forest cover change in a given location be acquired prior to any policy intervention. The findings were based on only 9 case studies from Africa out of the total 152 case studies. This small number of cases reinforces the assertion that processes of deforestation have not been generally well studied in Africa compared to other parts of the world (Lung and Schaab, 2010; Nagendra, 2007).

Another study about drivers of deforestation is reported in Nagendra (2007). This study was aimed at evaluating hypothesized drivers of forest cover change and identifying significant variables that appeared to impact forest clearing or regeneration in Nepal. Results showed tenure regimes, monitoring and user group size per unit of forest area were significantly associated with forest cover change while leadership was not. National forests were associated with deforestation while community and leasehold forests were associated with reforestation. Lack of monitoring was associated with deforestation while different levels of monitoring resulted into differing levels of reforestation. User group size per unit of forest area exhibited a curvilinear relation with 5 to 15 individuals per hectare of forest area providing maximum positive impact. Other factors that influenced forest change included management of social conflict, adoption of new technologies to reduce pressure on the forest, and involvement of users in forest maintenance activities. Recognizing that no single governance system could protect all forests, in all parts of the world, all of the time, it was recommended that studies be extended to other regions to identify factors that could help explain additional aspects of forest change in these locations. Mwavu and Witkowski (2008) analyzed land-use and cover changes within and around Budongo Forest Reserve in Uganda from multi-temporal images and field based studies (field observation, household interviews and key informant interviews) aimed at understanding the dynamics of land-use and cover changes, especially deforestation and associated agricultural developments from 1988 to 2004. Deforestation was found to be driven by a number of socioeconomic factors including agricultural expansion, increasing human population, unclear land tenure, conflicts of interest and political interference in addition to local people's perception that the forest was an obstacle to agriculture. Mwavu and Witkowski (2008) noted that sugar cane growing, which is known to have serious environmental impacts, is not subject to Environmental Impact Assessment (EIA), a legal requirement for any large development project in Uganda. In addition to demonstrating the haphazardness in environment management (Mwavu and Witkowski, 2008), it could also be a case of an institutional pro-deforestation measure (Geist and Lambin, 2002). Mwavu and Witkowski (2008) also agreed with Geist and Lambin (2002) that deforestation was associated with population increases as a result of in-migration.

Odada *et al*. (2009) examined ecosystem-level cases to determine causes of land-use and land-cover changes in the Lake Victoria Basin stretching across six countries. Core at the underlying level included climatic factors, economic factors, institutional factors, national and regional policies, population growth and other remote influences. The underlying factors drove cropland expansion, overgrazing, infrastructure extension and rates of land degradation at the proximate level. Drivers at local scales within the basin were not examined. *Odada et al*. (2009) noted a need for fine-tuning to localespecific dynamic patterns associated with inherent ecosystem changes. In yet another study within the Lake Victoria Basin, Lung and Schaab (2010) assessed land-cover dynamics and its drivers around three protected areas, Kakamega-Nandi forests in Kenya, Mabira and Budongo forests in Uganda. Results showed both Mabira and Kakamega-Nandi forests to have generally experienced continuous forest loss while Budongo showed a much more stable forest extent between early 1970s and 2003. There was also a clear relationship between forest loss and high population density suggesting population pressure as a major driver of deforestation.

Waiswa (2011) developed an empirical model of drivers of deforestation in Uganda’s Lake Victoria crescent where deforestation was found to have been a consequence of proximate causes which were triggered by a number of underlying drivers acting singly or in combination. The proximate causes included agricultural expansion into forests, extraction of wood forest products, and clearing of forests for non-agricultural uses. The underlying drivers included policy and institutional factors, economic factors, population growth, technological changes, changes in culture, and alienation of local people from forest resources. Alienation of local people from forest resources is posited as the most important underlying driver of deforestation as multiple underlying drivers lead to alienation of local people from forest resources, a scenario where an individual or a group of people feel disenfranchised of their rights to utilize or access resources.

In a nutshell, tropical deforestation is driven by a combination of several proximate (direct) and underlying (indirect) factors that acted at local, regional or global scales. The prominent proximate factors found in the literature include agricultural expansion, wood extraction and infrastructure extension while the underlying factors include economic factors, demographic factors, institutions, national policies, socio-cultural factors and alienation of local people from forest resources. All drivers of deforestation identified in the reviewed studies (Tangley, 1986; Bawa and Dayanandan, 1997; Place and Otsuka, 2002; Mwavu and Witkowski, 2008; Odada *et al*., 2009; Lung and Schaab, 2010, and Waiswa, 2011) generally fit into the classification of proximate and underlying factors.

(ii) New Perspectives

Deforestation in the tropics has been reported to be prevalent despite the existing interventions. This calls for further efforts to curb deforestation. The literature shows that deforestation is a result of both proximate and underlying drivers. However, most interventions such as evicting people from forest reserves tend to address the proximate (direct) causes of deforestation. Yet existing literature shows deforestation to be resulting from a number of underlying factors that drive the proximate causes. It is therefore important that pro-active rather than reactive approaches be adopted in curbing tropical deforestation; hence more focus being directed towards addressing underlying drivers of deforestation such as poverty.

Multiple underling drivers of deforestation in most cases lead to alienation of local people from forest resources which ultimately ends up driving the direct causes of tropical deforestation. It therefore appears that alienation of local people from forest resources posits itself as the major underlying driver of deforestation. Efforts that address alienation of local people from forest resources therefore have a high potential of combating tropical deforestation.

4. Conclusions

Based on existing literature, tropical deforestation can be attributed to a number of proximate causes that are influenced by a multiple of underlying drivers. The proximate causes include agricultural expansion, wood extraction and infrastructure extension while the underlying drivers include economic factors, demographic factors, institutions, national policies, socio-cultural factors and alienation of local people from forest resources. It is imperative that interventions addressing tropical deforestation focus more on its underlying drivers as this is a more pro-active approach than the generally reactive approach currently employed. And since alienation of local people from forest resources posits itself as a major underlying driver, pro-active approaches should aim at addressing it if tropical deforestation is to be combated.

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References

Bawa, K.S. and Dayanandan, S. (1997) Socioeconomic factors and tropical deforestation. *Nature* 386, 562-563.

Geist, H.J. and Lambin, E.F. (2002) Proximate causes and underlying driving forces of tropical deforestation. *Bioscience* 52(2), 143-150.

Lung, T. and Schaab, G. (2010) A comparative assessment of land cover dynamics of three protected forest areas in tropical eastern Africa. *Environmental Monitoring and Assessment* 61, 531-548.

Mwavu, E.N. and Witkowski, E.T.F. (2008) Land-use and cover changes (1988–2002) around Budongo Forest Reserve, NW Uganda: Implications for forest and woodland sustainability. *Land Degradation and Development* 19, 606–622.

Nagendra, H. (2007) Drivers of reforestation in human-dominated forests. *Proceedings of the National Academy of Sciences* 104(39), 15218-15223.

Odada, E.O., Ochola, W.O. and Olago, D.O. (2009). Understanding future ecosystem changes in Lake Victoria basin using participatory local scenarios. *African Journal of Ecology* 47 (Suppl. 1), 147-153.

Place, F. and Otsuka, K. (2000) Population pressure, land tenure and tree resource management in Uganda. *Land Economics* 76(2), 233-251.

Stephens, B.B. et al. (2007) Weak northern and strong tropical land carbon uptake from vertical profiles of atmospheric CO_2. *Science* 316, 1732-1735.

Tangley, L. (1986) Saving tropical forests. *Bioscience* 36(1), 4-8.

Waiswa, D. (2011) Dynamics of forest cover extent, forest fragmentation and their drivers in the Lake Victoria crescent, Uganda from 1989 to 2009. Ph.D. dissertation, Virginia Polytechnic Institute & State University, USA. Retrieved from http://scholar.lib.vt.edu/theses/available/etd-04122011-144641/

Managing Landscape Change by Means of Landscape Capacity and Sensitivity

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Abstract

Since changing landscapes mostly affect people's livelihood they require a better understanding. The European Landscape Convention defines landscape as an 'area, as perceived by people, whose character is the result of the action and interaction of natural and/or human factors'. The term landscape in the sense used here does not simply refer to the 'shape' of an area but rather to the 'appearance', including landforms, vegetation, soils, rivers, lakes etc. as well as the combined effects and processes. There are many approaches to this challenge. It can be done to determine the landscape capacity, i.e. the extent to which a particular landscape type is able to accept a particular kind of change without significant effects on its character. The capacity of a landscape for a specific type of change will depend upon the nature and magnitude of the change and the landscape's sensitivity. Capacity is closely associated with vulnerability, resilience and adaptation of landscapes. Its assessment is based on a detailed landscape evaluation done at different scales. In many parts of the world soils may demonstrate sensitivity to environmental changes that do not be confined to erosion. The complex factors involved in soil formation suggest soil as having the clearest expressions of landscape complexity. The better we succeed in deciphering the landscape's complexity the better we will be able to convert the concept of landscape sensitivity from a mere perception to a tool of integrated management approaches.

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1. Introduction

Not only since we are talking about the present climate change soil erosion has become a very common problem and much has been written on it so far. Soil erosion is by far the most serious form of land degradation. There are different forms of soil erosion like sheet and rill erosion whereas gullying is the most catastrophic form of it. Soil losses range from less than 1 t ha^{-1} yr^{-1} under dense natural vegetation to more than 50 t ha^{-1} yr^{-1} where steeply sloping land is farmed without conservation. The world's most severe soil erosion is possibly found in Ethiopia, Lesotho and Haiti (Young, 1998). Erosion in Ethiopia accounts to average rates of soil loss from 11 to 30 t ha^{-1} yr^{-1} (Moges & Holden, 2008) which according to Tamene & Vlek (2008) accumulate to 1.5 billion tons of top soil each year.

Gullies are steep sided trenches or channels, which are cut into poorly consolidated bedrock or soil by ephemeral flow of running water (fig. 1). They terribly express the vulnerability of a landscape's exposure to perturbations. There are many places in the world with even whole networks of gullies. Gullied areas or landscapes are widespread in Ethiopia. In densely populated parts of the Central Highlands of Ethiopia, entire hillsides have passed the threshold into the catastrophic stage of erosion and have been abandoned (Young, 1998)

Figure 1: Gully in southern Ethiopia (photograph taken by Birhanu Biazin)

Some authors addressed a rapid development of gullies over the last 30-40 years. There is much evidence for it in dambos in Malawi (Young, 1998) and in parts of southern Ethiopia (Moges & Holden, 2008). In Ethiopia it obviously has been a long lasting problem. With regard to the on-site effects according to Mesfin several reasons have left only an impoverished and exhausted soil in the country (Mesfin Wolde Mariam, 1984). Erosion has certainly played havoc with the country's most important resource, the soil (ibid.). There is a further historic indicator which refers to the off-site effects and that is based on paleoenvironmental reconstruction made in Tigray, northern Ethiopia. It suggests that the past 4000 years comprised three periods trending toward a steady state or equilibrium where the soil surface was stable, which they correlated to wetter periods, and two geomorphologic active phases, during which there was an increase of sediment yield from the slopes into the valleys (Machado et al. 1998). Even though this sediment yield does not only trace back to gullying it provides a useful proxy for soil erosion.

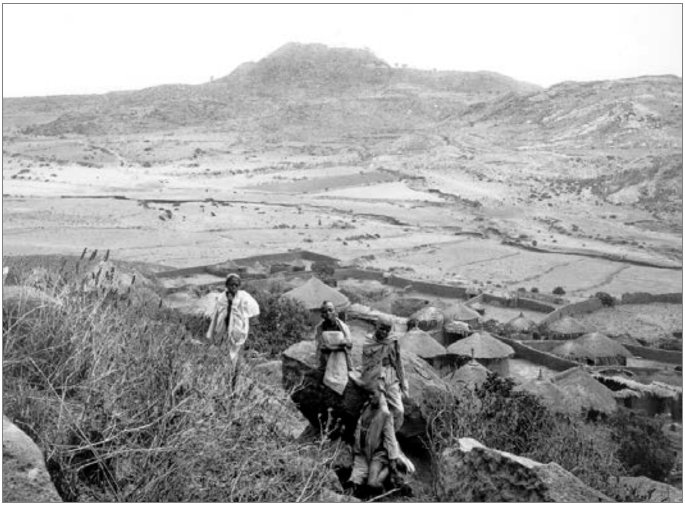

Figure 2: A typical bare landscape with gullies on the valley floor in northern Ethiopia (photograph taken by a member of the German expedition to Aksum/Tigray in 1906)

2. Causes and controls of soil erosion

Soil erosion and fertility decline are both forms of soil degradation that is part of land degradation. Land degradation is a human induced reduction of the productive capacity of land. In comparison to forest degradation and deforestation which also belong to land degradation normally severe soil degradation is irreversible.

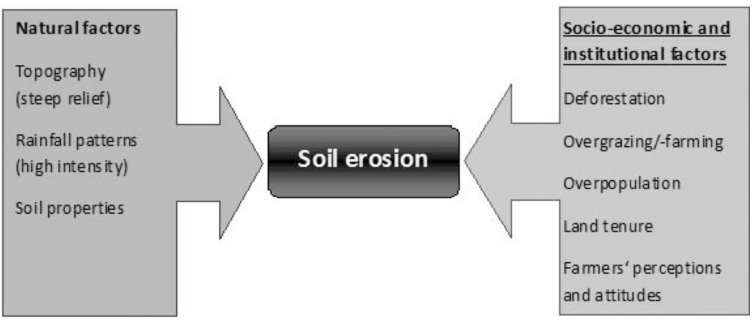

Figure 3: Main causes of soil erosion

In Ethiopia there are many causes of soil erosion like deforestation, cultivation of steep slopes and centuries of mismanagement in conjunction with rugged configuration and high intensity of rainfall (fig. 3). Considering deforestation as one of the main causes of erosion it is a moot question whether the forest cover in the Ethiopian highlands as a whole decreased from 46% to 2.7% of the land area between the 1950's and the late 1980's as stated by Yihenew Gebreselassie et al. (2009). Probably the bare landscape on figure 2 and Clarke's statement that in Tigray in the northern part of the country much of the forests having been destroyed well over a hundred years ago are revealing the situation at the beginning of the 20th century more realistic (Clarke, 1986) (fig. 2). Though soil erosion is a natural process it is mainly driven by land use practice.

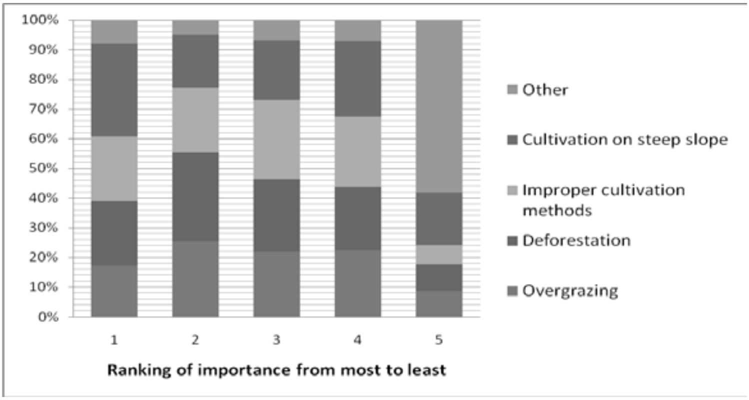

Figure 4: Farmers' perception on the causes of soil erosion on cultivated land,n Amhara Region

Source: Lakew Desta (2000)

And it is hardly surprising that the farmers' perception on the causes of soil erosion matches the scientific results, although their perception of the occurrence of soil erosion is assessed low (fig. 4).

3. Sensitivity, resilience and adaptation of landscapes

What about the controls of soil erosion? To quantify the amount of soil stripped from the farmland each year or to forecast it today it is common either to use the Universal Soil Loss Equation, like in the US, or mathematical models, like Germans prefer it. But whatever tool is applied it does not meet all demands to answer the problem since a sustainable soil system is much more complex (fig. 5).

Assuming that there is an area of virgin or untouched land with relative stability and healthy soils. First it starts with the external influence of land use that mostly causes soil erosion. Erosion produces sediment increases in rivers and decreases soil biodiversity considerably.

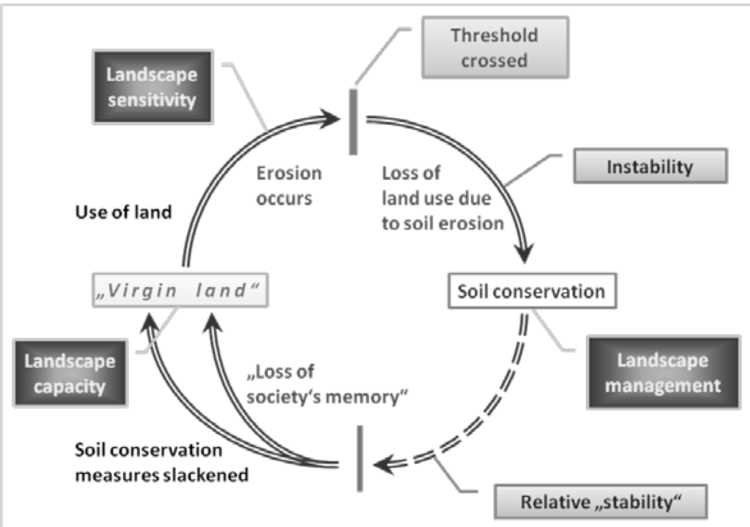

Figure 5: Soil erosion versus conservation (modified after M. B. Usher 2001)

Channel systems like gullies have a measure of elasticity that enables change to be absorbed by a shift in equilibrium. The amount of change a system can absorb before that natural equilibrium is disturbed depends on the sensitivity of the system. Landscape sensitivity in the sense used here means the likelihood of change, i.e. instability versus stability. High sensitivity indicates landscapes are vulnerable to the change whereas low sensitivity implies that they are more able to accommodate the change. According to Schumm sensitivity refers to the tendency of a system to respond to a minor external change. The change occurs at a threshold, which when exceeded produces a significant adjustment (Schumm, 1991). There are many drivers of change out of which the changing climate is one of most topical. However, the nub is why, when, where, and how often and how quickly do landscapes change?

Depending on the perturbation or stress the system reacts like any other stochastic system, i.e. if the system is near a threshold condition, a minor change may result in a dramatic response. In terms of soil erosion it leads to a loss of land use. This normally initiates soil and water conservation measures (SWC). In the case that this type of landscape management achieves success it may induce a phase of relative stability. But over large parts of the landscape that might be considered stable in geomorphic terms, soils may demonstrate sensitivity to environmental changes. The stability is both deceptive and elusive since the soil conservation measures are slackening due to a loss of society's memory. It is an apparent calm. And because the resilience of the system has been used up its function drove into a different state. The landscape has lost its ability to absorb the different magnitudes of that harm at the expense of its original characteristics. Consequently the process of the landscape's adaptation brought about a divergent state, i.e. virgin land No. 1 is unequal virgin land No. 2. Since land use is going on it seems to be a vicious circle. Not necessarily, a key to trigger the system is a better landscape management based on the assessment of landscape sensitivity.

4. Landscape management

With regard to soil erosion in Ethiopia there are two basic approaches. Mitigation involves taking actions to physically reduce the exposure of the farmers to soil erosion. It can take several forms. One form is to affect the cause of the hazard. But since soil erosion is among others caused by advanced tillage it is impossible to mitigate by stopping land use. A second type is to modify the hazard. This can involve engineering measures, such as check dams, stone or soil bunds, and fanya juus (literally, fanya juu means “throw soil uphill” in Kiswahili). Adaptation involves accepting that erosion will occur, or that it cannot be completely mitigated or eliminated.

The deficiencies included in mitigation and adaptation suggest an integrated management approach like modifying the loss potential. It combines elements of both mitigation and adaptation. If soil erosion cannot be reduced or modified, perhaps the community can take measures that reduce its sensitivity and vulnerability by providing education, practice, and organization. Both approaches are closely linked and could be added by spreading the loss. This applies only to economic and property losses. Farmers who suffer economic losses may be helped by relief organizations or charities or by the government. A clever combination of these approaches may offer successful answers to the problem. Landscape management is not least a problem of confidence.

Picture taken by J. Nyssen in 1994

Picture taken at the same spot by M. Schumacher in 2011

Figure 5: Obvious results of SWC measures in Northern Ethiopia

Fortunately land use in Ethiopia within the past two to three decades converted from just adaptation to mitigation in spite of the costs and the work load the construction and maintenance of SWC measures may take (fig. 5). Frankl et al. (2011) distinguish three major phases of landscape evolution in catchments of the Northern Ethiopian Highlands. After a historic phase of the extended formation of channels and gullies lasting roughly until 1965 in the second phase the processes seemed to have accelerated. In the third phase (ca. 2000-present) due to large scaled SWC measures these processes partly came to a stop. Some one quarter of the gully and river sections have stabilized. But for several reasons in this respect the southern parts of Ethiopia are behind in comparison to the north.

On the other hand it is not only a problem of confidence but also of motivation. For example opportunity costs can be very high, with bunds taking up 10-20 percent of cultivable area, and even more on sloped plots. Bunds therefore actually reduce the area under cultivation by a significant percent. In a study in the North-Western Highlands the farmers argued that they would destroy the introduced SWC measures in order to regain the “lost area” for cultivation; and some others stated that they would destroy some of the structures in order to use the fertile sediments retained behind. In other words, if farmers are to benefit from installing bunds, productivity must not only increase, but must exceed the lost caused by the reductions in cultivation area. One alternative is to plant trees or something else in order to provide the farmer with an extra bonus. This should be supplemented by searching for indigenous SWC measures.

References

Assefa D. Zegeye et al. (2009) Assessment of Hydrological and Landscape Controls on Gully Formation and Upland Erosion near Lake Tana. In: Improved Water and Land Management in the Ethiopian Highlands: Its Impact on Downstream Stakeholders Dependent on the Blue Nile, Intermediate Results Dissemination Workshop, February 5-6, Addis Ababa, Ethiopia.

Clarke, J. (1986) Ethiopia’s campaign against famine. Harney and Jones.

Esheteu Bekele, Ferdu Azerefegne, and Tsedeke Abate (2006) Facilitating the Implementation and Adoption of Integrated Pest Management (IPM) in Ethiopia. Planning workshop from October 13-15th 2003 at the Melkassa Agricultural Research Center, EARO; Jointly organized by the Association for Advancement of IPM (ASAI) and the Ethiopian Agricultural Research Organization (EARO); DCG (Drylands Coordination Group) Proceedings No. 17.

Frankl, A. (2011) Linking long-term gully and river channel dynamics to environmental change using repeat photography (Northern Ethiopia). *Geomorphology* 129, 238-251.

Hyndman, D. et al. (2009) Natural Hazards and Disasters. Nelson Education Ltd.

Lakew Desta et al. (2000) Land degradation and strategies for sustainable development in the Ethiopian highlands: Amhara Region. Socio-economics and Policy Research Working Paper 32. ILRI (International Livestock Research Institute), Nairobi, Kenya.

Machado, M. J., Pérez-González, A., and Benito, G. (1998): Paleoenvironmental Changes during the Last 4000 yr in the Tigray, Northern Ethiopia. *Quaternary Research* 49, 312–321.

Mazengia, W. and Mowo, J. (2012) Role of collective actions in integrated soil and water conservation: The Case of Gununo Watershed, Southern Ethiopia. *Journal of Development and Agricultural Economics* 4(1), 23-36.

Mesfin Wolde Mariam (1984) Rural Vulnerability to Famine in Ethiopia 1958-1977. Vikas Publishing House, New Delhi.

Miles, J. (2001) Landscape sensitivity: an ecological view. *Catena* 42, 125–141.

Moges, A. and Holden, N. M. (2008) Estimating the rate and consequences of gully development, a case study of Umbulo catchment in Southern Ethiopia. *Land Degrad. Develop.* 19, 574–586.

Demelash, M. and Stahr, K. (2010) Assessment of integrated soil and water conservation measures on key soil properties in South

Gonder, North-Western Highlands of Ethiopia. *Journal of Soil Science and Environmental Management* 1(7), 164-176.

Poesen, J. et al. (2003) Gully erosion and environmental change: importance and research needs. *Caten* 50, 91– 133.

Schumacher, M. (2012) Recent Trends in Gully Erosion as Evidenced by Repeat Photography around Hagere Selam (Northern Ethiopia) (unpublished).

Schumm, S. A. (1991) To interpret the Earth: ten ways to be wrong. Cambridge University Press.

Tadesse, M. and Belay, K. (2004) Factors Influencing Adoption of Soil Conservation Measures in Southern Ethiopia: The Case of Gununo Area. *Journal of Agriculture and Rural Development in the Tropics and Subtropics* 105 (1), 49–62.

Tamene, L. and Vlek, P.L.G. (2008) Soil Erosion Studies in Northern Ethiopia. In: Braimoh, A.K. & Vlek, P.L.G. (ed.): Land Use and Soil Ressources, Springer.

Thomas, M.F. (2001) Landscape sensitivity in time and space — an introduction. *Catena* 42 (2–4), 83–98.

Usher, M. B. (2001) Landscape sensitivity: from theory to practice. Catena 42, 375–383.

Yihenew Gebreselassie et al. (2009) Lessons from Upstream Soil Conservation Measures to Mitigate Soil Erosion and its Impact on Upstream and Downstream Users of the Nile River. Improved Water and Land Management in the Ethiopian Highlands: Its Impact on Downstream Stakeholders Dependent on the Blue Nile Intermediate Results, Dissemination Workshop, February 5-6, Addis Ababa, Ethiopia.

Young, A. (1998) Land resources: now and for the future. Cambridge University Press, Cambridge.

Changing Land Use Systems and Land Degradation in Arid Climate of Sudan: an Overview of Risks and Impacts

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Abstract

Sudan, many cultivated areas, both irrigated and rain fed, which had natural vegetation pattern are subjected to land degradation. The objectives of this overview were to investigate the risk of changing of the natural vegetation land to crop production system; to assess the measure used to overcome constraints and to highlight the precautions that have to be taken in advance. The overview covered the studies carried at Umjawasir project and Alhudi in North states. Umjawasir project was started in 1992 as irrigated crop production project, to provide economic self-reliance for drought displaced nomads, it consists of three phases: phase zero (unprotected phase), phase I and phase II (protected phases). After three years unprotected phase (zero) invaded by sand and was abandoned. As a protection an earth embankment was constructed for phase I and phase II and as a result only 35%and 25% of cultivated area of phase I and II respectively, were invaded by sand. By time, the embankment developed into dunes near the farm, serving as a secondary sand source, and the project sustainability was at risk. The high wheat production and the new life established at the area demonstrated that the project could achieve its goal therefore, the sustainability of the production is crucial and biological measure could be the solution. For the objective of this overview, detail

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study on shelterbelt performance done at Alhudi shelterbelt (with the same climate) was highlighted. The study aimed at assessing the influence of the shelters on capability of wind to erode the soil windward and create dust and sandstorm .From wind measurements, the results indicate that species of *Acacia ehrenbergiana* and *Acacia seyal* or other species of this family are not suitable for first row of the shelterbelt. The appropriate shelterbelt design is irrigated, maximum of three rows with its height increased from outside to inside, and proper management is crucial for better growth and efficiency.

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1. Introduction

Land degradation as wind or water erosion is a serious environmental problem worldwide and a major threat to the sustainability of agriculture and economic development. I n semi-arid degradation continues unabated and many of the causes and the consequences have been extensively studied. Drifting sand is one of the land degradation; every year swallows a considerable area of land and negatively affects the sustainability of agricultural systems in semi-arid climates. Wind is the erosive agent; when it blows strong enough over a surface of sand, they give their momentum to these particles, causing them to creep or saltate, or get into suspension. When the sand is set in motion, saltation begins causing avalanching, that may destroy the vegetation cover while such cover itself is the most effective means to suppress moving sand (Bagnold, 1941; Chepil and Woodruff, 1963; Wilson and Cook, 1980; Wolfe and Nickling, 1993). The rate of avalanching depends on the width of the eroding field and as the wind dislodges transports and deposits particles, sorts the surface decreasing the soil fertility (Zobeck and Fryear, 1986).

To overcome the problem of drifting sand one of the following approaches can be used: deposition of drifting sand upwind of the area subject to the sand invasion; enhanced transportation over the area under threat; reduction of the sand supply; or deflection of the moving sand. Ditches, barriers, fences and vegetation belts are means to mitigate the impacts of drifting sand. Their protection effectiveness depends on wind speed and duration, biomass distribution of the vegetation, and shape, height and porosity of the barrier (Rocheleau et al. 1988; Lyles 1988; Nickling and Wolfe 1993). Natural scattered trees are effective in suppressing moving sand (Nicholas 1988; Al-Amin et al. 2004). The effect of shelterbelt on soil moisture and fertility has been well quantified worldwide (Winpenny, 1991) and its role in suppressing drifting sand were done in wind tunnel experiments (Cornelis *et al.*, 1997). Few scattered data, on shelterbelt and scattered trees as a barrier to suppress blowing sand, are available for African countries (Anderson, 1987; Nicholas, 1988; Amin *et al*., 2010; Shulin *et al*., 2008; Mohammed *et al*., 1999).

In Sudan, many cultivated areas, both irrigated and rain fed, which had natural vegetation pattern are subjected to land degradation in particular blowing sand. Crop production in semi-arid regions where drifting sand is prevailing is problematic. Creating s or decreasing soil surface roughness enhances sand settlement, with consequent change in soil level critical for gravity irrigation systems. In these situations, the sustainability of crop production lands is at risk while protection using different measures is questionable). Umjawasir irrigated project for wheat production in the Northern State, in a semi-arid climate, which was natural vegetation subject to blowing sand is an example. The objectives of this overview were to assess the sustainability of the project and to investigate the risks of changing the natural vegetation land cover to crop production system and to evaluate the measures used to overcome constraints and to highlight the precautions that have to be taken.

2. Material and Methods

The review covered the study that was carried at Umjawasir project and Alhudi shelterbelt in River Nile state. The Umjawasir irrigated crop production project was started in 1992 to contribute to economic self-reliance for drought displaced nomads. It consisted of three phases: phase zero (unprotected phase), phase I and phase II (protected phases). The area is irrigated from underground water using pumps. For that six wells were used for each phase. For the purpose of this study areas were classified as well 1-6 and wells 7-12 for phase I, and II respectively. The sustainability of the project was assessed using the total production, the cultivated area and the abandoned area. To assess the impacts of blowing sand the starting area of each phase was used as reference to which the areas abandoned due to moving sand were compared. Phase zero was unprotected therefore was taken as a reference for protected phases to assess the role and efficiency of the earth embankment which was constructed as a mechanical measure for protection.

For comparison purposes, the study conducted by Dafa-Alla and Nawal (2011) at Alhudi shelterbelt that implemented at pumping station 5 was highlighted to evaluate the efficiency of the shelterbelt as a biological measure to protect farm from drifting sand. Alhudi shelterbelt, is around 4 km, was investigated to show its efficiency and the constraints that hindered its establishment. It was six years old and aiming at protection of the station from moving sand that affect the mechanical parts of the pumping units. It composes of equally spaced at 3m*3m, tree species: *Acacia seyal* (Del), *Acacia ehrenbergiana* (Forsk.) Hayne, and *Ziziphus spina*-christi (L) Deaf, *Azadirechta indica* A. Juss, *Conicarpus lancifolius*, and *Acacia amplicips* Maslin. Based on shelterbelt configuration two well defined segments on the shelterbelt were recognized (belt 1 and belt 11). Belt 1 begins with *Acacia seyal*, while that of belt 11 begins with *Acacia ehrenbergiana*. The efficiencies of the belts were monitored by the reduction of velocity of blowing wind and hence its capability of creating dust and sand storm. Vertical and horizontal wind measurements were made on windward, during north prevailing wind (6-10 January 2010) using a programmable data logger a CR800 (Campell Scientific) connected to an electrical cup anemometer that consists of three conical cups for counting. Horizontal measurements were taken at the following distances from the shelterbelt upwind: 0.25h, 0.5h, 1h, and 2h (h= belt height) and at two different levels 0.25h and 0.5 h. Reference anemometer was used in an open area for the two levels and distances. Ten-minutes average wind speeds were measured simultaneously for the two levels at each position, and at different times during the day for each position for duration of two hours. The capabilities of the shelterbelt were estimated and predicted by applying the windbreak protection efficiency model. The model shows that small reduction in wind speed would result in large soil erosion control where wind erosive force for loose sandy soil is considered proportional to cubic wind speed, Bird et al. (1992) as follows:

$$R = \frac{w_t}{w_o} \qquad (1)$$

Where:

R = wind reduction ratio, Wt = the wind speed at any level for any distance from the tree (average wind speeds of 2 h), Wo = the wind speed at the same level in the open (average wind speeds of 2 h).

3. *Results and Discussion*

3.1. Project Sustainability

Wheat production (ton/ha) and cultivated area per season for phase I and II, are shown in Fig. 1 and Fig. 2, respectively. Phase I started with 63 hectare in 1999 and then decreased in the following seasons and phase II started in 2000 with 112 ha and by 2006 only third of the area was cultivated for both phases (less than 20 ha for phase I and 30 ha for phase II). Productivity showed the opposite, as cultivated area decreases the land productivity increases for example, in 2006, 20 ha in phase I produced more than two fold of 63 ha cultivated in 1999 which produced only 0.8 ton/ha and 112 ha cultivated in 2000 gave 0.3 ton/ha compared to 0.8 ton/ha that produced in season 2006 by 39 ha of phase II. Availability of irrigation water could explain this situation therefore sustainability is questionable.

In table 1and table2cultivated area and production in ton per hectare for each well for seasons19999-2004 and season 2006 of phase I and seasons 2000-2004 and 20006 for phase II are shown. In Phase I, area (well 1) under cultivation decreased while production increased for the first four seasons and for season 2003- 2006 areas of these wells were completely abandoned. This trend is almost the same for others areas of wells 3, 5 and 6, except for wells 2 and 4 which, had been continually cultivated. Although many factors could be the reasons to abandon these areas but the main factor is the sand invasion. In table 3, 100% of phase zero was completely buried by sand and abandoned and as a result of the earth embankment used to protect phase I and II, 35% of phase I was invaded. The temporary effectiveness of the protection is demonstrated in table 2 where for phase II all areas were continuously cultivated particularly for the first four seasons and by time the earth embankment, accumulating sand and serves as a secondary source and for that 25% of this phase was abandoned. The two earth embankments, that were established to protect the land suppressed sand, deposited moving sand and by time serving as a secondary source plate 2. The area is subjected to the sand where the amount of moving that passed along one meter per year was about 3.5 m^3/m. This explains the short life span of the earth embankment, and the need for more effective measures to overcome the threat of sand (Alamin et al., 2010) shelterbelt could be the solution.

Fig. 1: Cultivated area and its production for season 1999 -2004 and 2006 at Phase I-Umjwasir project

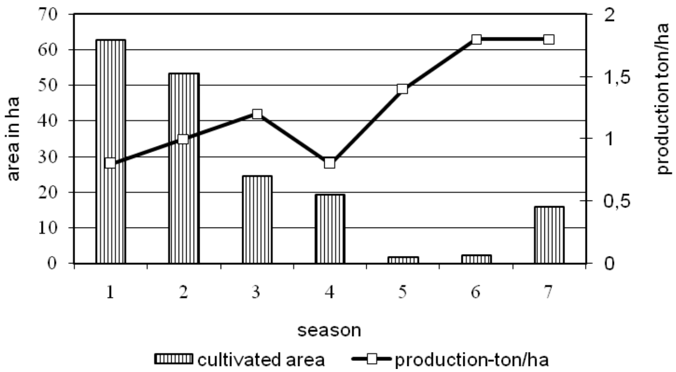

Fig. 2: cultivated and its production for season 2000 -2004 and 2006 at Phase II-Umjwasir project

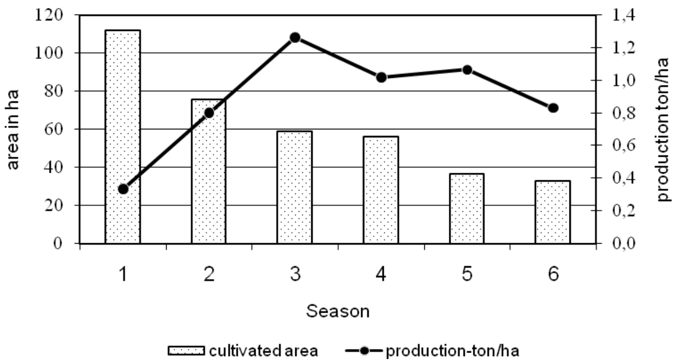

Table 1: Cultivated area in ha and its wheat production in ton/ha for the 6 wells, of phase I of Umjawasir project, for seasons1999-2004 and 2006.

well	1999		2000		2001		2002		2003		2004		2006	
	area	Pro.	area	Pro.	area	Pro.	area	Pro.	area	Pro.	area	Pro.	area	Pro.
1	14	0.7	9	0.9	7	1.2	0	0.4	0	0.0	0	0.0	0	0.0
2	11	0.8	13	0.8	5	1.4	8	0.8	2	1.4	1	1.9	9	2.1
3	10	0.8	11	0.7	3	1.3	0	0.0	0	0.0	0	0.0	0	0.0
4	9	0.5	7	0.9	3	1.0	5	0.8	0	0.0	1	1.7	2	2.6
5	9	1.1	9	1.1	3	0.9	4	0.6	0	0.0	0	0.0	3	1.2
6	10	0.7	5	1.3	5	1.2	3	0.8	0	0.0	0	0.0	3	2.2

*Pro. = production

Table 2: Cultivated area in ha and its wheat production in ton/ha for the 6 wells, of phase II of Umjawasir project, for seasons 2000-2004 and 2006.

well	2000		2001		2002		2003		2004		2006	
	area	Pro.	area	Pro.	area	Pro.	area	Pro.	area	Pro.	area	Pro.
1	18	0.4	13	1.2	11	1.2	9	0.9	7	0.9	4	1.0
2	18	0.1	13	0.5	10	0.9	10	0.7	6	0.5	3	1.0
3	19	0.4	13	0.9	9	1.3	8	1.1	7	1.2	3	1.2
4	19	0.6	13	1.3	10	1.9	9	1.5	7	1.5	11	0.1
5	19	0.3	13	0.6	10	1.4	14	1.2	11	1.2	13	0.9
6	18	0.1	13	0.3	10	0.8	8	0.6	0	0.0	0	0.0

*Pro. = production

Table 3: The cultivated area for phase (zero, I, and II), the area invaded by sand and the percentage of abandoned area with respect to the started area after three years (2000-2002) at Umjawasir farm.

Phase	Cultivated area (ha)	Invaded area (ha)	Abandoned area
Zero	40	40	100%
I	63	22	35%
II	112	28	25%

3.2. Protection Measures

Detail study at Alhudi shelterbelt has been done by the authors assessing the impact of the presence of the shelterbelts on blowing wind which is driving force of moving sand. In tables 4 and 5 the erosive force was estimated at two levels from the soil surface of each shelterbelt and at gaps between trees of the first row showed that near the soil surface (0.5h) *A. ehrenbergiana* had lower impact on wind erosive force compared to *Acacia seyal* (Talih) species. *A. ehrenbergiana* reduced the wind speed up to 78% reducing the erosive force to 47% while gaps between *Acacia seyal* (Talih) increased the wind speed to 116% thereby increasing the wind erosive force up to 154%. Alhudi belts had bad growth performance. They consist of six rows, irrigated by drip, and during the first three years had suffered shortage of water. This showed that the main constraint for shelterbelt at this area is availability of water. The result demonstrates that even small reduction ratio could largely reduce the erosive force of the wind and therefore control wind erosion particularly if leeward protection is considered. The adopted configuration of Alhudi shelterbelt is inefficient in reducing wind speed and sand deposition. A windbreak must be dense near the ground. For this purpose, always choose a dense, bushy deciduous or evergreen shrub for the windward row of a multiple-row planting. Results also show that although Alhudi belts II and I are that have room to develop than with five seriously overcrowded rows. Crowding trees in a windbreak causes a loss of vigor due to severe competition as the trees try to increase in size. Lower limbs die out early from too much shade in an overcrowded planting, thus making the windbreak much less effective because of lower density next to the ground. The seasons govern porosity of many species, and therefore influence the effectiveness of the windbreaks (Tibke, 1988). This may be true for Alhudi shelterbelt as wind speed measurements were taken during January where deciduous trees are partially shaded. However, this further call for a better species selection and windbreak configuration made up of six rows, their growths was poor and were not effective.

Table 4: Shelterbelts wind reduction ratio (R) and related reduction in wind erosive force (E) of Nile Estate - North Sudan. Wind speed measured at level 0.25h for 10 minutes intervals and averaged for two hours at each location (h stand for belt height).

Level 0.25h						
Distance	0.5h		1h		2h	
	R	E	R	E	R	E
Alhudi I	0.86	64%	0.91	76%	0.98	95%
Alhudi II	0.93	81%	0.90	74%	0.91	76%
Level 0.5h						
Distance	0.5h		1h		2h	
	R	E	R	E	R	E
Alhudi I	0.86	64%	0.88	68%	0.87	65%
Alhudi II	0.85	62%	0.90	73%	0.91	76%

Table 5: Shelterbelts wind reduction ratio (R) and related reduction in wind erosive force (E) at gap between trees of the first row of Alhudi belt I and belt II. Wind speed measured for 10 minutes intervals and averaged for two hours at each location (h stand for belt height)

Level	**0.25h**		**0.5h**	
	R	E	R	E
Gap I *Acacia ehrenbergiana*	0.96	88%	0.91	75%
Gap 2 *Acacia ehrenbergiana*	0.78	47%	0.75	42%
Gap 2 *Acacia ehrenbergiana*	1.6	154%	0.68	32%
Gap 2 *Acacia seyal*	0.84	60%	0.73	38%

The amount of protection is not directly related to the number of rows but to the density or porosity of the windbreak. The effect of any barrier in reducing the rate of soil movement depends on the wind velocity and direction, the threshold velocities needed to initiate soil movement, and the barrier shape, width, height and porosity (Tibke, 1988). A five-row planting makes a very desirable farmstead windbreak. The best performance usually is obtained by using a different kind of tree or shrub in each row. Following the traditional windbreak design suitable plant combination of a multiple row irrigated shelterbelt includes a dense shrub, medium sized deciduous, tall deciduous, medium evergreen and tall evergreen for successive rows starting windward (WSU, 2003).In dry areas, supplemental irrigation can reduce the number of rows used in a windbreak or make the standard number of rows more effective. For example, two or three rows of trees given supplemental irrigation easily equal five rows depending only on natural precipitation. Results will be better with three rows that have room to develop than with five seriously overcrowded rows. Crowding trees in a windbreak causes a loss of vigor due to severe competition as the trees try to increase in size. Lower limbs die out early from too much shade in an overcrowded planting, thus making the windbreak much less effective because of lower density next to the ground. The seasons govern porosity of many species, and therefore influence the effectiveness of the windbreaks (Tibke, 1988). This may be true for Alhudi shelterbelt as wind speed measurements were taken during January where deciduous trees are partially shaded. However, this further calls for a better species selection and windbreak configuration.

4. Conclusion and recommendations

The overview demonstrated the risk of changing natural vegetation land to agricultural in semi-arid area subject to blowing sand indicated the effectiveness of trees and shrubs to suppress moving sand compared to other mechanical measures. Using mechanical measure to deposit drifting sand creates sand dunes near the area and serves as a secondary sand source therefore additional measure has to be implemented. The effectiveness of a shelterbelt depends on its design; height and porosity. From wind measurements, the results indicate that species of *Acacia ehrenbergiana* and *Acacia seyal* or other species of this family are not suitable for first row of the shelterbelt. The appropriate shelterbelt, in semi-arid, design is irrigated, maximum of three rows with its height increased from outside to inside, and proper management is crucial for better growth and efficiency. The high wheat production and the new life established at the area showed that the project could achieve its goal therefore, the sustainability of the production is crucial and biological measure could be the solution.

References

Al-Amin N.K. Nasr and Stigter C.J. and Mohammed, A.E. (2010) Wind reduction pattern around isolated biomass for wind- erosion control in desertified area of central Sudan. *Research, Journal of Environmental and Earth Sciences* 2(4), 226-234.

Al-Amin, N.K.N. (2010) Drifting Sand Endangering Gezira Irrigation Scheme in Central Sudan, History and Impact, accepted. *Journal of Agricultural Science and Technology*, USA.

Al-Amin, N.K.N. (2010) Semi-arid Vegetation Pattern, Stability and Suitability to Suppress Sand Movement in Central Sudan. Accepted research paper, *Asian Journal of agricultural Sciences.*

Anderson, D. (1987) The economics of afforestation: A case study in Africa. World Bank Occasional Paper (New Series). Baltimore, Md.: Johns Hopkins University Press.

Bagnold, A.R. (1941) The physics of blown sand and desert dunes. Methuen & Co.L London.

Bird, P.R., D. Bicknell, P.A. Bulman, S.J.A. Burkie, J.F. Leys, J.N. Parker, F.J. Van Der Sommen and P. Voller (1992) The role of shelter in Australia for protecting soils, plants and livestock. *Agroforest. Syst.* 20, 59-86.

Chepil, W.S. and Woodruff, N.P. (1963) The physics of wind erosion and its control. *Advances in Agronomy* 15, 211-301.

Cornelis, W.M., Gabriels, D. and Lauwaerts, T. (1997) Simulation of Windbreaks for Wind-Erosion Control in a Wind Tunnel. Proceedings of Wind Erosion: An International Symposium/Workshop held at Kansas State University, Manhattan, Kansas, USA, June 3-5, ttp://www.weru.ksu.edu/symposium/proceedings/ cornelis.pdf.

Dafa- Alla. M.D. and Al-Amin N.K.N. (2011) Design, Efficiency and

Influence of a Multiple-Row, Mix-Species Shelterbelt on Wind Speed and Erosion Control in Arid Climate of North Sudan. *Research Journal of Environmental and Earth Sciences* 3 (6), 655-661. Lyles, L., 1988. Basic wind erosion processes. Agric. Ecosyst. Environm. 22/23, 91-101.

Mohammed, A.E., Stigter, C.J. and Adam, H.S. (1999) Wind regimes windward of a shelterbelt protecting gravity irrigated crop land from moving sand in the Gezira Scheme (Sudan). *Theor. Appl. Climatol*. 62, 221-231.

Mohammed, A.E., Stigter, C.J., Adam, H.S. (1995) Moving sand and its consequences in and near a severely desertified environment and a protective shelterbelt. *Arid Soil Res. Rehab.* 9, 423-435.

Nichkling, S.G. and Wolf, A. (1993) The protective role of spare vegetation in wind erosion. *Progress in Physical Geography* 17 (1), 50-68.

Nicholas, I.D. (1988) Plantings in tropical and subtropical areas. *Agric. Ecosyst. Environ.* 22/23, 265-482.

Rocheleau, D., Weber, F. & Field-Juma, A. (1988) *Agroforestry in dryland Africa*. International Council for Research in Agroforestry. Nairobi, Kenya.

Shulin, L., Tao, W., Guangting, C., Jian, G., Xian, X. and Shaoxiu, M. (2008) Field investigation of surface sand and dust movement over different sandy grass lands in the Otindag Sandy Land, China. *Environ. Geol.* 53, 1225-1233.

Tibke, G. (1988) Basic principles of wind erosion control. *Agric. Ecosyst. Environ*. 22/23, 103-122.

Wilson, S.J. and Cook, R.U. (1980) Wind Erosion. In: John Wiley and Sons, New York.

Winpenny, J.T. (1991) Values for the environment. A guide to economic appraisal. Overseas Development Institute.

Zobeck, T. M., Fryear, D.W. (1986) Chemical and physical characteristics of windblown sediment II. Chemical characteristics and total soil nutrient discharge. Trans. ASAE 29(4), 1037-1041.

Economics & Social Aspects of Reducing Degradation & Deforestation in Savanna Forests Used for Wood fuels

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Abstract

Forests of savanna woodlands in Sudan constitute the main source of wood fuels for the domestic sector. Firewood is mainly used by rural communities, which in most of the cases is collected for free. Savanna woodlands are also exploited for production of wood fuels in commercial basis, which is transported for use mainly in urban centers. Supply of wood fuels constitutes one of major factors of deforestation of the savanna woodlands and degradation of reserved forests. In response to reacting to global community concern about climate change, efforts are directed to reduce deforestation and forests degradations. Carbon projects, which take into consideration national and local communities' needs in particular for wood fuels provide viable option, and guarantee participation of communities. The financial analysis proved that including production of wood fuels as an additional value in carbon projects increase the profitability of such projects. Analysis was based on modest estimates for cost items of carbon projects, degree of carbon density and deforestation rate. Further investigations to study these parameters are recommended.

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1. Introduction

1.1. Background

IPPC defined degradation as the persistent reduction of canopy cover and/or carbon stocks in a forest due to human activities such as animal grazing, fuel wood extraction, timber removal or other such activities, but that does not result in the conversion of forest to non-forest land, while deforestation as the long-term or permanent removal of forest cover and conversion to a non-forested land use. REDD projects aim to avoid the conversion of forests to non-forested areas (deforestation) or to avoid activities that reduce their carbon stocks without leading to outright conversion (degradation). It is worth noting that the VCS distinguish between legal and illegal degradation and logging. Only illegal, or unplanned, degradation and logging form part of the REDD category, while areas that have been designated or approved for logging by regulatory bodies fall into the Improved Forest Management (IFM) category (Olander 2011).

The Sudan Forestry Sector Review 1986 estimated forest area of Sudan to be about 94 million ha. The report estimated the savanna woodlands in total to constitute about 75.53 % of total forest area equivalent to about 70.90 million ha. The savanna zone constitutes the main zone in which rain fed agriculture is practiced in form of traditional rain agriculture and mechanized farming. The forests in savanna zone are also being utilized in unsustainable basis for wood fuels needs. The trend of pattern of use of savannah woodlands is resulting in increasing rate of deforestation and forest degradation in the savanna zone, and consequently a continuous reduction of area classified as forest land. Blue Nile State represents a good example which experience deforestation and degradation of savanna woodlands.

In response to reacting to global community concern about impact of forest degradation in climate change, the authorities are in the process of coming up with carbon projects. Carbon projects, if only considered from point of view of revenues from carbon credits may have social impact in the livelihood of rural communities. Carbon projects have to consider also other values provided from existing use of those forests. Olander and Johannes 2011 reported that, though some restoration or conservation projects may be focusing on carbon as the primary or sole source of revenue, aiming to create more than one revenue stream can lead to a much more resilient and attractive project.

1.2. Objectives

The paper investigates the economics and social aspects in connection with carbon projects for savanna woodlands with consideration to community and national needs and in particular to needs for wood fuels taking the state of Blue Nile as an example. The investigation addresses following issues:

- Drivers of deforestation and degradation in savanna woodlands.
- Reducing deforestation and degradation and securing national and local communities' needs from wood fuels
- Costs and benefits in implementing carbon projects with consideration to the benefits from wood fuels production in sustainable basis.

2. Deforestation and degradation in savanna woodlands

Deforestation and degradation in the natural savanna woodlands as well as reserved forests in the savanna belt is resulting mainly from the conflicting land use practices, especially the excessive pressure from the nomadic herds, clearing of land for cultivation of crops, and use of forests for wood fuels in commercial basis. There was a trend of continuous increase in annual areas cultivated under mechanized rain fed farming and decrease in areas cultivated under traditional rain fed agriculture sector. Areas cultivated under traditional sector in year1983 and 1990 was 5.17 million ha and 4.72 million ha, while areas cultivated under mechanized farming were 2.00 million and 4.24 million ha respectively. In Blue Nile State the areas of mechanized crop farming increased from 640000 ha in 1983 to 1400000 ha in 1990, while areas under traditional rain fed farms decreased from 874000 ha in 1983 to 667000 ha in 1990 (Abdelsalm 1992). Thirab 2007 reported that areas of rain fed mechanized farming in Blue Nile State in 2003 reached in total about 3.86 million ha. The practice in the traditional sector is what is known as shifting cultivation, which may give chance for natural growth in abandoned areas. Impact of use of land for agriculture in deforestation is mainly a result of expansion in mechanized farming.

Production of wood fuels in general and charcoal in particular in commercial basis is a major factor contributing to degradation of savanna woodlands forests. Savanna forests of Blue Nile state till the eighties of last century constitute the main province for charcoal production and supplier to main consuming centers of Khartoum and other urban centers. According to forest law of 1932 production of charcoal should come from reserved managed forests, but the forest authorities in Blue Nile concentrate the commercial production outside forest reserves in areas planned for future expansion for agriculture production (Abdelsalam 1992). Starting from nineties the quantities of charcoal transported from the state to main urban centers declined in comparison to quantities transported from other states. There is no reliable data on the illegal production from wood fuels. The official recorded average annual production of the state from charcoal during the eighties was about 2.5 million sacks annually. In 1992 the officially recorded legal production from all central states transported to Khartoum was estimated to be 6.2 million sacks of charcoal (Abdelnour et al 1995). The Savanna natural woodland in Blue Nile state constitutes also the major sources of firewood for rural communities in the state as well as some of urban needs. As for the case of charcoal, there is no reliable data on the illegal commercial production from firewood. The 2001 household survey indicates that the average percentages of population who use firewood in rural and urban sector were 82% and 69% respectively. State wise use, the high percent of use of fire wood is in the states of western Sudan and in Blue Nile State. The percentage of rural population who use fire wood in those states is in the range of range of 95% -100 %. Also the higher percent of wood collection is found on those states. The report indicates that, most of the rural communities who use firewood for cooking collect the wood from natural wood lands. The impact of wood collection by rural communities on degradation is not that much compared to commercial use.

Although there is good progress in rate of reservation of savanna forest lands, the rate of deforestation due to these factors is also increasing. The total area of the reserved forests in 1990 was estimated to be about 4.8% of the total area of the country. In addition to that, the total area occupied by other protected areas (game reserves) represents 5.7% of the total area of Sudan. Area of total forest reserved in savanna woodlands were estimated in 1990 to be around 0.62 million ha, areas proposed for reservation about 1.4 million ha, out of that there were about 144000 ha reserved, and 487000 ha proposed for reservation in Blue Nile province (Abdelsalam 1992). According to forestry authority areas of reserved forest in Blue Nile State reached about 312000 ha in 2005. In most of those reserved forests, not all the area of the forest is fully stocked, in particular in parts of the forest areas, which were temporary used for agriculture. Mohyeldin 2012 indicated that, in some parts of Rawashada reserved forest there is no sign of natural restocking.

3. Considering national and local communities needs in REDD projects

Cheikh et al 2012 reported that, the current definition of REDD+ is expected to include AR (Afforestation/Reforestation), IFM (Improved Forest Management), and REDD (Reduced Emissions from Deforestation and Forest Degradation) project types. Reducing degradation and deforestation in reserved forests of savanna woodlands requires in first place good protection for controlling the illegal use of the forest and protection against fires outbreaks. Community participation can have important role to this aspect. There is a serious risk of increased leakage and reduced (carbon) permanence when local communities are impacted negatively, marginalized, or even excluded from project opportunities. On the other hand, appropriate participation by communities increases local buy-in and social sustainability, thereby mitigating these risks (Blomley 2011).

In his management plan for Rawashda savanna woodland forest reserve in Eastern Sudan, Vink 1987 reported that, no longer should the rural people, whether sedentary or nomadic be seen as antagonistic, but they should be treated as fellow users of the same resource, whose needs must be taken into account in management of the forest. Such needs if not satisfied will represent an opportunity cost which has to be taken into consideration. World Bank report 2011 reported that, opportunity costs include, most obviously, the forgone economic benefits of the alternative land use. Preventing the conversion of forests to other land uses, can significantly affect the livelihoods of many rural dwellers.

Previous studies revealed that poor rural communities, will not go up in the energy ladder, but rather they will go down when access of communities to wood fuel resources became limited. Study by Elamin 2011 in Gezira State, where wood fuel is becoming scarce, revealed that most of rural women revert to use of agriculture residues (cotton stalks) and use of modern fuels is limited. The result is that more women are exposed to health hazards. In other hand study by Ahmed 2001, revealed that rural communities displaced to outskirts of urban centers (IDPs) will still use wood fuels and mainly in form of charcoal, but with less number of meals cooked per day, and this have its social implications. These facts indicate the importance of planning for provision of wood fuels in sustainable basis, since demand for it will not change significantly in near future. Urban centers importing wood fuels, as well as rural sector in the state will continue depend on wood fuels in the near future. Abdelsalam 2001 forecasted the pattern of energy use in household for year 2020 taking year 1995 as base under different scenarios, he found that, the quantities of wood fuels to be supplied for satisfying the demand under best scenario of substitution by modern types of fuels, will still be higher than quantities of wood fuels demanded in base year. Mhyeldin 2013 indicated that in study by WISDOM international showed that there is a deficit in meeting demand for wood fuels from available resources in eastern region of the country, and the study suggested importing wood fuels from Ethiopia. Covell, Phil 2011 reported that, in many cases, carbon revenues from carbon projects (mainly designed for carbon credits as revenue) will be insufficient to sustain a sound forestry or forest conservation project. Carbon revenues will need to be complemented by other income streams.

The management plan developed by Vink 1987 as part of FAO project (fuel wood Development for Energy in Sudan) for Rawashda forest reserve of Kassala State as model for savanna woodlands, can be adapted and used for other reserved savanna forest areas in developing of carbon projects which takes into consideration national and local communities needs. The plan divides the reserved area of Rawashda forest into five working circles), namely the national wood fuel working circle (constituting 68 % of reserved forest area), village working circle (13 %), protection circle, Hashab circle, and fodder production circle. The plan provided prescriptions for wood production circle to be managed in sustainable basis with a rotation of 20 years. Vink 1987 reported that, a wood fuel rotation of 20 years for acacia seyal is an accepted compromise in the literature on the subject. He estimated a yield of 4.2 and 4.3 m3 / ha from thinning on age of 11 and 15 years, and 15.3 m3 / ha from final felling. The plan considered restocking of degraded parts of the forests by planting or direct sowing with Acacia seyal. Goda et al 1998 investigated restocking of savanna reserved woodland of Khor Donia in Blue Nile Province with acacia seyal and the exotic tree of eucalyptus species. The study recommended the use of the native species of the area (Acacia seyal) for restocking of the degraded forest.

4. Assessment of financial feasibility

While there is no fixed lower bound, most market intermediaries and investors look for projects offering 10,000-20,000 tons of CO_2 emissions reductions per year, at a bare minimum. This means, for example, that it will be difficult for AR projects covering less than a few thousand hectares to be economically viable, especially if slow-growing tree species are used. This size barrier might be overcome if areas form part of an aggregated set of projects, known as Grouped Projects (Olander 2011). Assuming a total of 10000 ha of reserved forest in will be conserved for carbon credits in a carbon project, an estimate of possible cash flow from carbon project can be made based on available estimates of some parameters from literature and on some assumptions. The analysis is based on estimate of an average carbon density of 50 tons /ha with price of \$ 5 / ton, an annual cost of protection per ha of \$ 2, a deforestation rate of 0.4 %, and a reduction in emission due to deforestation of 90 %. Accordingly an initial assessment of feasibility from the carbon project is calculated as follows:

i. Carbon stock= Average carbon density x area= 50 x 100000 = 5000000 tons co2

ii. Annual emissions= Carbon stock x deforestation rate x carbon reduction = 5000000 x 0.4 % x 90 % = 15000 tco2/ yr

iii. Emission reductions= Annual emission x Effectiveness avoiding degradation = 15000 x 80 % = 12000 ton co2/yr

iv. Then the revenue from carbon sale can come up to $ 60000 per year

v. If we assume that the initial cost of developing the project will cost about $ 100000 and that there will be a cost of $ 40000 each year for implementing the project, the none discounted revenue will be $ 20000 each year, and discounted revenue with 12 % discount rate for the first 20 years starting from year 1will be: 17860, 15940, 14240, 12720, 11340, 10140, 9040, 8080, 7220, 6440, 5740, 5140, 4580, 4100, 3660, 3260, 2920, 2600, 2320. 2080

vi. The cumulative discounted cash flow for 20 years starting from year 1 will be, -82140, -66200, -51960, -39240, -27900, -17760, -8720, -640, +6580, +12890. 18030, 22610, 26710, 30710, 33630, 36550, 39150, 41470, 43550

The example shows that, with 12 % discount rate of return, the project after 9 years can break even, and the net present value is less than 50 % of initial cost. Considering Acacia seyal as the appropriate species to be used for wood fuels production in the national and village wood fuels circles, and applying the same discount rate of 12 % the net discounted revenue is estimated. The undiscounted expected revenue is based according to prices prevailing to date for cubic meters of wood in production sites, which was provided by forest authorities in the state. Vink 1987 reported that, the cost of felling is approximately half the cost of value of wood produced. Costs incurred in year zero were estimated in $ from previous study in Khor Donia which included land clearing, harrowing, sowing, weeding and cost of fire lines. The results of calculations of net discounted revenue for 20 years gave a discounted revenue per of 8.2 dollars/ ha (Table 1).

Table 1: Estimates of expenditures and revenues per ha for a 20 years rotation of Acacia seyal applying 12 % discount rate

Year	Multiplier	Expenditure ($)	Dis. Expend. ($)	Revenue ($)	Dis. Revenue ($)
0	1.000	25.90	25.90	0.00	0.00
1	0.893	04.00	3.60	0.00	0.00
10	0.322	35.00	11.30	90.00	29.00
15	0.183	35.00	6.40	90.00	16.50
20	0.104	100.00	10.40	280.00	29.10
OH/ yr	9.818	.90	8.80	0.00	
Total		200.80	66.40	310.00	74.60
Net					8.20

The results indicates that in 20 years, the net revenues from wood fuels if we are using equal forest area , and same discount rate of 12 % is comparable with expected net revenues from carbon credits. We should also take into consideration that, the cost of project development may be higher than the assumed value, and the discount rate of interest of 12 % in fact is very low for discounting carbon projects. In the other hand, additional values other than carbon credits such as none timber products (gums) can be obtained from areas which will be conserved for protection purposes.

5. Conclusions and Recommendations

Savanna woodlands in general and in Blue Nile State in particular constitute a major part of forestry cover in Sudan and source of fuel wood and support of livelihood of rural communities. The illegal use of the land for agriculture and for commercial production from wood fuel is resulting in deforestation and forest degradation.

Change of population to use modern fuels instead of traditional fuels is constrained by prevalence of poverty. Most of rural communities will continue depend on traditional fuels in near future. Efforts directed for conservation of forests in carbon projects have to consider the role of those forests in provision of national needs and needs of the poor local communities for wood fuels in particular. This will ensure their participation in protection of the forests.

Financial analysis proved that including production of wood fuel as an additional value in carbon projects increase the profitability of those projects, in addition to contribution of solving wood fuel crisis, and reduces risk from leakage.

The feasibility of carbon project was calculated based on modest estimates of cost of development of carbon projects, carbon density, deforestation rate, and annual costs of protection, more investigation will be required to quantify these parameters for savanna woodlands.

References

Abdelnour, H.O., Abdelsalam, A.A., Salih, I.A. (1995) Sustainable wood fuel supply for Khartoum State. HABITAT Workshop on Household Energy needs for Khartoum State. Khartoum.

Abdelsalam, A.A. (2001) Evaluation and forecasting trends pattern of energy demand for cooking in household sector. Proceedings of 5th Scientific Conference 1 -19 April 2001. Ministry of Science Technology, National Center for Research, Khartoum.

Abdelsalam, A.A. (1992) Investigation on planning supply and optimizing transport of charcoal from savanna woodlands. PhD. Institute of International Forestry and Forestry Products, TU Dresden.

Ahmed, M.E. (2001) Household's energy consumption pattern in displaced areas in Khartoum State Sudan: Case study in Hay Albaraka. M.Sc. Dis., Institute of Environmental Studies, University of Khartoum.

Blomley, T. and Richards M. (2011) Community Engagement Guidance: Good Practice for Forest Carbon Projects.

Mbow C. et al. (2012) Challenges and Prospects for REDD+ in Africa: Desk Review Of REDD+ Implementation in Africa. GLP Report No. 5. GLP-IPO, Copenhagen.

Covell, P. (2011) Business Guidance: Forest Carbon Marketing and Finance. In: Ebeling, J. and Olander, J. (eds.).Building Forest Carbon Projects. Washington, DC: Forest Trends.

Elamin, S. and Elhasan, M. (2011) The impact of gender roles in modern energy transition process in Gezira rural areas of Sudan. PhD. Dis. Department of Environmental Sciences and Natural Resources, Faculty of Agricultural Sciences, University of Gezira, Sudan.

Goda, S., Abdelsalam, A., Abdelmagid, T. and Mohamed, M. (1998) Feasibility Study for a Tree Plantation Enterprise in Khor Donia Reserve – Blue Nile Sudan.

Ministry of Energy & Mining 2001: Sudan 2nd national energy assessment, Household sector report. Ministry of Energy & Mining, Khartoum.

Mhyeldin, F. (2013) Draft report of management of Rawashda forest. Unpublished draft management plan for Rawashda (In Arabic).

Olander, J., and Ebeling J., (2011) Building Forest Carbon Projects: Step-by-Step Overview and Guide.

Seifert-Granzin, J. (2011) *REDD* Guidance: Technical Project Design. In: Ebeling, J. and Olander, J. (eds.). Building Forest Carbon Projects, Washington, DC: Forest Trends.

Thirab, M.O.S.A (2007) Rain fed mechanized agriculture in Sudan: Facts and Numbers. (in Arabic).

Vink, A.T. (1987) Integrated land use plan for Rawashda Forest Reserve (Kassala Province, Eastern Sudan) 1987–1991. Fuel Wood Development for Energy, GCP/ SUD/ 033/ NET.

World Bank (2011) Estimating the opportunity costs of REDD: A training Manual, Version 1.3, World Bank Institute.

Mapping Land Use Change Using Multi-Sensor Satellite Data in the Eastern Nile Basin of Sudan

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Abstract

This study was conducted in the Eastern Nile (EN) Basin in the Gadarif Region of Sudan. Severaldecades of intensive dry land farming within the study area has led to rapid land use/land cover (LULC) changes mainly due to agricultural expansion, government policies and environmental calamities such as drought. In this paper an attempt has been made to analyse and monitor the LULC changes using multi-sensor satellite data during the period 1979 – 2010. The applied data were obtained from Landsat, ASTER, TerraSAR-X and Geo-Eye satellites. For this, a post-classification comparison, object-oriented classification and field-based land cover classification techniques were used to detect LULC changes from the different satellite images. The results showed that a significant and extensive change of LULC patterns has occurred during the last three decades in the study area. The combination of TerraSAR-X data and the object-oriented classification approach resulted in more detailed LULC maps compared to Landsat and ASTER data. However, the best classification result was obtained from the 2-m resolution Geo-Eye data in terms of class number and classification accuracy. We conclude that, using combinations of medium and very high resolution optical and active remote sensing data as well as different classification techniques will assist in sustainable land use management within the EN Basin.

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1. Introduction

Information on LULC is an important element in forming policies regarding economic, demographic, and environmental issues at national, regional and global levels. It has been a commonly held notion that the change of land use pattern has always been an important cause to the environmental degradation observed in the EN Basin. In general, LULC classification simplifies the spectrum of natural diversity by reducing to a finite number of manageable classes (Dobson et al., 1995; Al Fugara et al. 2009). Over the last few decades, numerous researchers have improved measurements of land cover change, the understanding of the causes of land use change, and predictive models of LULC change (Taylor et al., 2002; ZhengHai et al., 2007). Recently, multi-sensor satellite data have been used for wide remote sensing applications including LULC changes (Wolter and Townsend, 2011). Optical remote sensing data were used extensively in LULC classification during the past decades. However, the use of synthetic aperture radar (SAR) sensors is becoming more important in many disciplines of remote sensing applications (Bruzzone et al., 2004). They can play an important role in several application domains dealing with the production of LULC maps, especially in the cases where optical remote sensors fail due to the unavailability of cloud-free data. Employing of multi-temporal very high-resolution optical remote sensing data coupled with multipolarisation SAR data will have great potential in LULC change mapping. Therefore, the objective of this study is to analyse and monitor the LULC changes using multi-sensor satellite data during the period 1979 – 2010.

2. Methodology

2.1 Study Area

The Eastern Nile (EN) Basin constitutes about half of the area of the Nile River and contributes about 86% of the average annual flow of the main Nile River. It supports an extraordinary range of ecosystems from high mountain moorlands, afromontane forests, savanna woodlands, extensive wetlands and arid deserts. The EN Basin encompasses about 1.7 million km2 and comprises four sub-basins: the Baro-Akobo-Sobat (White Nile) in the west, the Abbay (Blue Nile), the Tekeze-Setit-Atbara on the east and the Main Nile from Khartoum to the Nile Delta (Figure 1). It is home to about 109 million people that constitute about 74% of the total Nile River Basin population. Gadarif Region is located in the Tekeze-Atbara-Setit sub-basin. This sub-basin covers an area of about 230000 km2. It consists of the Tekeze river (known as the Setit in Sudan), and its tributaries, the Goang (Atbara in Sudan) and Angereb, all of which originate in the north central highland plateau of Ethiopia.

The study area is located in the eastern part of the Gadarif Region 13.86° – 14.23° N and 34.99° – 35.27° E with a gentle slope of 0–1%. Gadarif Region covers a total area of approximately 78000 km^2. The region displays semi-arid climatic conditions where rainfall is erratic and concentrated in only few months of the year, mainly from June to October. The annual rainfall in the northern part is less than 500 mm. Temperatures range from a mean minimum of 22° C in winter to a mean maximum of 37° C in summer, while it may reach 40 – 42° C in April or May. The land use system is dominated by agriculture, which includes sorghum and sesame cultivation, livestock rearing and forestry.

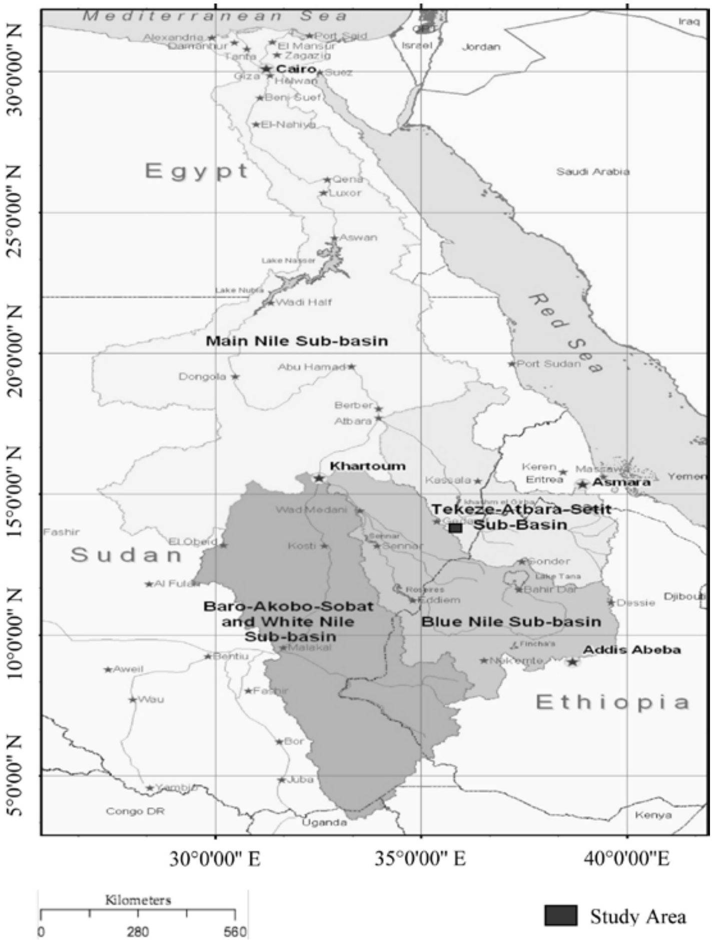

Figure 1: Location of the study area in the EN Basin

2.2. Data and Image Pre-processing

The data used in this study are illustrated in Table 1. The Landsat Multispectral Scanner (MSS), Thematic Mapper (TM), Enhanced Thematic Mapper Plus (ETM+), TerraSAR-X (TSX) and Geo-Eye images were geo-referenced to the Level 1B ASTER image of the year 2009 which is geometrically corrected using approximately 30 well-distributed ground control points (GCPs). The Landsat MSS, TM, ETM+ and ASTER images were resampled into a pixel size of 30 x 30 m. However, pixels of the TSX and Geo-Eye images were resampled to a size of 4 x 4 m and 2 x 2 m respectively. Normalising of the backscatter coefficient (BSC) and speckle reduction were applied to the TSX data using a method as described by Infoterra, 2008.

2.3. Image Processing

A supervised classification-based maximum likelihood classification (MLC) method was employed to Landsat and ASTER data in order to classify the individual images independently (Richards and Jia, 2006). For the same set of data a multi-date post classification comparison (PCC) change detection algorithm was used to determine the LULC changes in four periodic intervals: 1979–1989, 1989–1999, 1999–2009 and 1979–2009. ERDAS IMAGINE 8·7® (ERDAS, Inc., Norcross, GA) image processing software was used for overall image processing.

Table 1: Properties of the data used in the study

Satellite	Acquisition date	Spectral bands	Ground resolution
Landsat-3 MSS	05.Nov.1979	1 – 4 bands	57 m
Landsat-5 TM	16.Dec.1989	1 – 7 bands	30 m
Landsat-7 ETM+	21.Nov.1999	1 – 7 bands	30 m
ASTER	17.Jan.2009	1 – 3 bands	15 m
Geo-Eye	18.Nov.2010	1 – 4 bands	2 m
TerraSAR-X:		Polarisation	
TSX 1	07.Nov.2009	HH & HV	4 m
TSX 2	12.Nov.2009	HH & HV	4 m

For TSX data, the Definiens developer software version 7.0 (www.definiens.com) was used for object-oriented classification which includes image segmentation and classification tools. Image segmentation was created by means of the multi-resolution segmentation (MRS) algorithm introduced by Baatz and Schäpe (2000). The MRS was applied to the both HH and HV polarisations.

The tested MRS parameters which were based on trails are listed in Table 2. The image weight in segmentation is equal for each polarisation. Due to unavailability of high resolution optical data or aerial photograph for the study area during the growing season of the year 2009/2010, the segmentation results were evaluated by using the field survey data obtained during images acquisition time. The nearest neighbour classifier of the feature space optimisation (FSO) tool applies the user-selected samples method as reported by Benz et al., (2004). In the FSO procedure, each object can be characterised by a number of features. These features include spectral, shape, and textural data (Platt and Rapoza, 2008). Several features were tested using a combination of HH and HV bands. The two TSX images were mosaiced to cover the entire study area.

Table 2: Tested segmentation parameters
(smoothness/compactness was constant at 0.5/0.5)

Segmentation level	Scale parameter	Colour/Shape	Image weight (HH:HV)
Level 1	250	0.9/0.1	1 : 1
Level 2	250	0.8/0.2	1 : 1
Level 3	150	0.9/0.1	1 : 1
Level 4	150	0.8/0.2	1 : 1

Field-based land cover classification using object-based image analysis (OBIA) was applied to the Geo-Eye data. Using the Definiens developer software version 7.0 a total of 32 spectral and textural values were tested (Table 3). Then in order to separate between each class pair the Bhattacharya Distance and the Jeffries–Matusita Distance equations were used (Mahmoud et al., 2011). Applying the membership functions of the Definiens developer software the class description was assigned. These functions offer transparent relationship between feature values and the degree of membership to a class.

In order to assess the classification accuracy, error matrices were plotted as cross-tabulations of the classified data versus the reference data to the all data set applied in this study.

Table 3: List of the tested features for the Geo-Eye data classification

Features	Descriptions
Spectral:	
1. Mean	Brightness, Maximum difference (Max. diff.),[1]layer1, layer2 &layer3
2. Standard deviation	Layer1, layer2 & layer3
Texture (after Haralick):	
1. Homogeneity	GLCM[2] all dir., layer1, layer2 & layer3
2. Contrast	GLMC all dir., layer1, layer2 & layer3
3. Dissimilarity	GLMC all dir. [3], layer1, layer2 & layer3
4. Entropy	GLMC all dir., layer1, layer2 & layer3
5. Mean	GLCM all dir., layer1, layer2 & layer3
6. Standard deviation	GLCM all dir., layer1, layer2 & layer3
7. Correlation	GLCM all dir., layer1, layer2 & layer3
8. Ang. 2nd moment	GLCM all dir., layer1, layer2 & layer3

[1] layer 1 = blue, layer 2 = green & layer 3 = near infrared; [2] GLCM = Grey-Level Co-Occurrence Matrix

3. Results and Discussion

General patterns of the LULC class identified in the Landsat MSS (1979), TM, (1989), ETM+ (1999) and ASTER (2009) images were largely dominated by cultivated land, woodland and fallow land areas (Figure 2). Cultivated land was found to have the largest area within the study region and the rate of its change was observed to be unsystematic. The severity of risks facing farmers in agriculture varies because of various factors such as farming system, environmental, technical and policy factors. These factors are limiting the cultivated area within a particular season. Mustafa (2006) reported that in the mechanised large-scale farming system of the Gadarif Region, three types of risks are predominant, namely, production, market and financial risk. These risks are likely to be the main reasons for the temporary change of cultivated land in the study area. The high dynamics of woodland area was mainly due to the expansion in the agricultural areas. The large utilization of the study area for mechanised rain-fed agriculture took place during the first part of the study period (1979–1989), and by end of the study period (1999–2009); most of the land was under cultivation. However, the increase of the woodland area in the year 1999 is mainly attributed to the reforestation activities, which have been made by the Sudanese

National Forest Corporation following the drought years during the 1980s. These findings agreed with the results obtained by Brink and Eva (2009) in sub-Saharan Africa over a period of 25 years (1975–2000). The increase of fallow land during the last stage of the study period (1999–2009) was mainly attributed to high decline in the soil fertility, which resulted in increasing the fallow age by the farmers to more than 10 years in some cases (MFC, 2009). The expansion trend of the settlement areas was observed to be close to a constant rate during the three stages of the studied period. The rapid expansion of the settlement areas was mainly due to socioeconomic processes, which were closely associated with the agricultural activities within the study area. During the three stages of the studied period, bare land appeared to have increased moderately. Similar type of results has been reported by Tsegaye et al. (2010) in the Tigray Region of Ethiopia, which is adjacent to study area.

The overall LULC classification accuracy levels for four dates of satellite images ranged from 86 to 92% with Kappa indices of agreement ranging from 76 to 88%.

The object-oriented classification approach applied to the TSX data was effective in producing more generalised and close-to-reality LULC maps without mixed classes and boundary effects. The classification shown in Figure 3 resulted into nine LULC classes with an overall accuracy amounts to 84.7% and Kappa Index of agreement of 82 %. This accuracy is considered high although it is less than that have been obtained by the previous optical data. However, more detailed LULC classes have been detected by the TSX data. This was mainly due to the high resolution of the SAR data as well as the use of dual polarisation in the classification process.

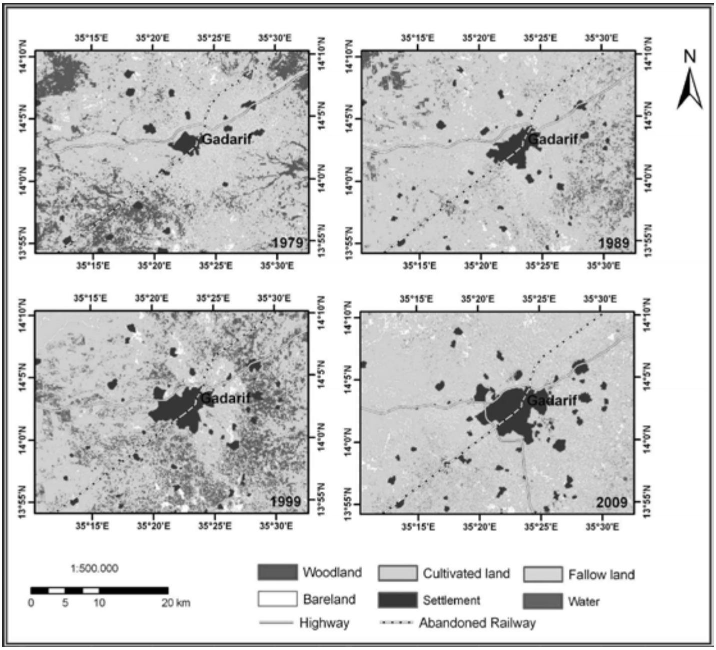

Figure 2: LULC maps of the years 1979 (MSS), 1989 (TM), 1999 (ETM+), 2009 (ASTER)

Furthermore, applying the object-oriented classification approach through using of the spectral, shape and textural features for the image classification helped in identified more classes. This becomes clear form separating the class settlement (urban areas) into two sub classes: "Settlement 1" which consists of metal-roof buildings and the buildings made from the local material such as wood, mud and grass; and "Settlement 2" which represents the concrete (roof) buildings. The class harvested land could not be discriminated from the cultivated land, despite the availability of both optical and SAR data acquired in the same season. However, in the optical data the class rock was classified as part of the bare land. Therefore, the obtained classification accuracy indicated that TSX data has the potential for operational LULC mapping in the EN Basin. Since the existing land use within this region is characterised by complex and scattered patterns of small and large agricultural fields. The classification of the Geo-Eye data resulted into eleven LULC types as depicted in Figure 4. Some classes can be separated and classified accurately using only one layer of the used Geo-Eye image, while other classes require a combination of the three layers to increase the classification accuracy. It can be seen that classes such as: plant residues, field boundaries, railway, track road and road were obviously mapped when applying the field-based land cover classification to the 2-m resolution Geo-Eye image. An overall accuracy assessment of 94% with kappa coefficient of 91% was achieved.

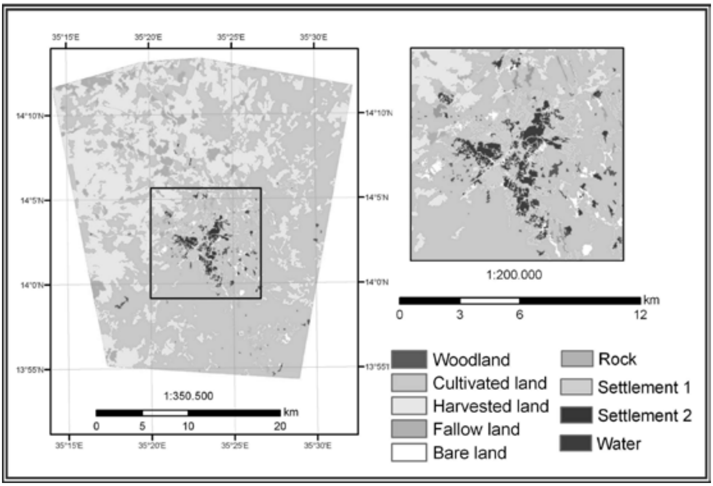

Figure 3: LULC map obtained by the TSX data. Gadarif city is shown in the frame

4. Concluding Remarks

Based on the LULC analysis of Landsat and ASTER data of the years 1979, 1989, 1999 and 2009, we found that the LULC change trends varied significantly during the above mentioned periods. The expansion of the mechanised rain-fed agriculture as a result of deforestation is considered as one of the main driving forces for the LULC change in the study area. The potential of TSX dual polarisation data for LULC mapping in the EN Basin was evaluated. The applied object-oriented classification technique is applicable for data with different polarisation. The FSO function was used to calculate the features that separate the classes best. The field-based land cover classification method applied to the Geo-Eye data using the spectral and textural parameters shows the best classification result in terms of class number and classification accuracy. The findings of the study serve as a testimony of the applicability of multi-sensor satellite data for LULC mapping at a detailed scale.

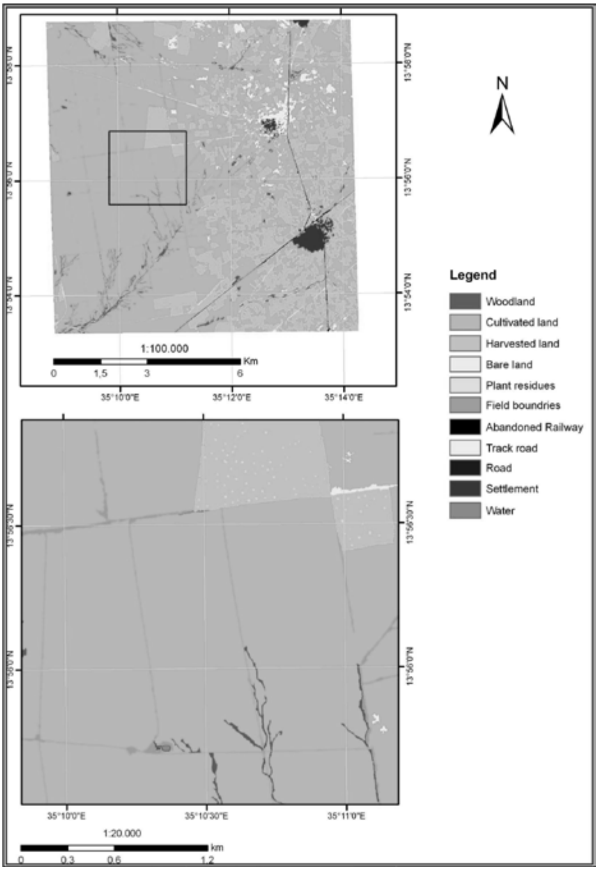

Figure 4: LULC map resulted from the Geo-Eye data. The frame shows the field boundaries and plant residues of the harvested land.

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References

Al Fugara, A.M., Pradhan, B., Mohamed, T.A. (2009) Improvement of land-use classification using object-oriented and fuzzy logic approach. Applied Geomatics. 1, 4, 111–120.

Baatz, M. & Schäpe, A. (2000) Multiresolution segmentation – an optimization approach for high quality multi-scale image segmentation. In: STROBL, J. et al. (Hrsg.): Angewandte

Geographische Informationsverarbeitung XII. Beiträge zum AGIT-Symposium Salzburg, September 2000, Karlsruhe, Herbert Wichmann Verla, 12–23.

Benz, U.C., Hofmann, P., Willhauck, G., Lingenfelder, I. & Heynen, M. (2004) Multi-resolution, object-oriented fuzzy analysis of remote sensing data for GIS-ready information. ISPRS

Journal of Photogrammetry and Remote Sensing, 58, 239–258.

Brink, A. B. & Eva, H. D. (2009) Monitoring 25 years of land cover change dynamics in Africa: A sample based remote sensing approach. Applied Geography, 29, 501–512.

Bruzzone, L., Marconcini, M., Wegmüller, U. & Wiesmann, A. (2004) An Advanced System for the Automatic Classification of Multitemporal SAR Images. IEEE Transactions on Geoscience and Remote Sensing, 42, 6, 1321–1334.

Dobson, M. C., Ulaby, F. T., Pierce, L. E., Sharik, T. L., Bergen, K. M., Kellndorfer, J., Kendar, J. R., Li, E., Lin, Y. C., Nashashibi, A., Sarabandi, K. L. & Siqueira, P. (1995) Estimation of forest biomass characteristics in northern Michigan with SIR-C/X-SAR data. IEEE Transactions on Geoscience and Remote Sensing, 33, 877–894.

Infoterra GmbH. (2008) Radiometric calibration of TerraSAR-X data. Technical document No. TSXX-ITD-TN-0049-radiometric_calculations_I1.00.

Mahmoud, A., Elbialy, S., Pradhan, B. & Buchroithner, M. (2011) Field-based landcover classification using TerraSAR-X texture analysis. Advances in Space Research, 48, 799–805.

MFC (2009) Unpublished records and statistics, Mechanized Farming Corporation (MFC), Gadarif, Sudan.

Mustafa, R. H. (2006) Risk Management in the Rain-fed Sector of Sudan: Case study, Gadarif Area Eastern Sudan. Ph.D Thesis, Justus – Liebig University, Giessen, Germany.

Platt, R. V. & Rapoza, L. (2008) An Evaluation of an object-oriented paradigm for land use/land cover classification. The Professional Geographer, Association of American Geographers, 60, 1, 87–100.

Richards, J. A. & Jia, X. (2006) Remote Sensing Digital Image Analysis. 4th edition. Springer-Verlag Berlin Heidelberg, 194 – 199.

Taylor, C., Lambin, E. F., Stephenne, N., Harding, R. & Essery, R. (2002) The influence of landuse change on climate in the Sahel. Journal of Climate, 15, 24, 3615–3629.

Tsegaye, D., Moe, S. R., Vedeld, P. & Aynekulu, E. (2010) Land-use/cover dynamics in Northern Afar rangelands, Ethiopia. Agriculture, Ecosystems and Environment, 139: 174–180.

Wolter, P. T. & Townsend, P. A. (2011) Multi-sensor data fusion for estimating forest species composition and abundance in northern Minnesota. Remote Sensing of Environment, 115, 671–691.

ZhengHai, L., GuoBao, s., HaiYan, L., YaJing, B., JiXi, G., HaiMei, W., Tian, X. & Yan, C. (2007) Analysis of land use change and its driving force in the

Impacts of Disposed Petroleum Produced Water on Soil and Trees at Khartoum Refinery – Sudan

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Abstract

The main objective of this study was to assess the impact and potential risks of disposed produced petroleum water (DPPW) on the ecosystem in the study area through assessing the quality of produced water effluent in different treatment stages and the impact of produced water on the soil and vegetation cover in the study area. The research was conducted in Khartoum Refinery Company about 70 kilometres north of Khartoum - Sudan on the eastern bank of the River Nile. Data collected from the study area included: 1) Water samples were collected from three treated bonds and were analyzed for PH, EC, OC, TSS, TDS, CO3, HCO3, Na, Ca, Mg, Pb, Cd and Zn; 2) soil samples were collected from DPPW irrigated area (forestry project) which plantations trees established since year 2004 to 2011, and from un irrigated areas as a control. They were analyzed for: pH, EC, ESP, SAR, Na, K, Ca, CO3, HCO3, NH3-N, Mg, Pb, Cd and Zn. 3) A survey and measurements of trees height and diameters to the breast in forestry project were done. Also chemical foliar for trees leaves were under processing.

The result of this study, indicate that as irrigation duration increased, there was an increase in soil salts content of EC, ESP, SAR especially in the sites which were irrigated for eight and four years and that

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indicate the a tendency to accumulate salts with increasing of irrigation duration within depths. The situation indicates that continuing irrigation with this water could develop a saline sodic soil, and sodicity will damage the physical prosperity particularly water movement. This finding supported by the general morphology of the plantation there were more trees falling, dryer, burn, with more bare space area and shorter in heights and smaller diameters when irrigated with treated water than other tree plantations.

The study strongly recommends that stakeholders should develop risk-based corrective actions by enhance methods of treatment water to decease percentage of salts in irrigation water to clean up environmental pollution from produced water in the area of oil production and industry.

1. Introduction

Oil Production and industry is an important sector in the Sudan economy, but with negative impacts, such as pollution from contamination with by-products. The largest source of waste has been the water separated from the crude coming out of the wells which is known as produced water. For that reason, the single most significant environmental impact for crude oil production in Sudan is finding proper environment, friendly means for the disposal of produced water. The high amounts of contaminants is produced water, (salts, hydrocarbons, well treatment chemicals, oil separation and water treatment chemicals) can reach toxic concentrations that will pollute the surrounding areas, especially soil and waters, if dispersed directly into them.

Oil exploration, production, transportation, storage, refining, marketing, distribution and final use of products and exportation contribute considerably environmental degradation, especially in the industrialized world. In large concentrations, the hydrocarbon molecules that make up crude oil and petroleum products are highly toxic to many organisms, including humans. Petroleum also contains trace amounts of sulphur and nitrogen compounds, which are dangerous by themselves and can react with the environment to produce secondary poisonous chemicals (Johnson, 2010). Although oil is used worldwide as the main source for energy, it threatens the natural environment as its composition is made of complex molecules which when burned produce relatively high levels of carbon dioxide, sulphur dioxide and nitrogen oxides. Global warming, the increase of average world temperatures as a result of the greenhouse effect, is one of the impacts of the escalating oil use. Carbon dioxide contributes by about 50% to the greenhouse effect, in addition to methane, chlorofluorocarbons and nitrous oxide (Elredaisy, 2010).

There is increasing environmental concern about the ocean discharge of contaminants, such as metals and hydrocarbons, in produced water because of their potential for bioaccumulation and toxicity, particularly by those dissolved in the water phase (Neff 2002; Neff et al. 2006). The environmental impact of the oil industry includes the land use, waste management, groundwater and air pollution from the production and refining processes. Carbon dioxide, a greenhouse gas, and other harmful gases and waste materials are produced. The oil may be transported vast distances by tanker and pipeline, adding to its impact on the environment. Accidents such as oil spills would cause additional damage to the ecology. Waste waters released by crude oil-processing and petrochemical industries are characterized by the presence of large quantities of crude oil products, polycyclic and aromatic hydrocarbons, phenols, metal derivatives, surface-active substances, sulphides, naphthylenic acids and other chemicals (Suleimanov, 1995). Due to the ineffectiveness of purification systems, wastewaters may become seriously dangerous, leading to the accumulation of toxic products in the receiving water bodies with potentially serious consequences on the ecosystem (Beg,2001; beg et al ., 2003).

The Khartoum Refinery Company abbreviated to (KRC) specialize in refining crude petroleum in Sudan, it was founded in 1997 and began operations in 2000. The total capacity for refining amounts to (550) thousand barrels per day in the term of crude oil. The water supply together with industrial and sanitary drainage systems include a water purification station of (1.5) thousand cubic meters per hour and an extinguishing station with a capacity between (800) and (500) cubic meters per hour. Cooling water works at (13,300) cubic meters per hour, while that for industrial water processing and sanitation works at (300) cubic meters per hour. Petroleum production is about 2.2587 metric tons per hour, ranging from gasoline to liquefied gas, in addition to a substantial amount of water as a major waste by-product. The amount of waste water is estimated to be about 20 million m^3 / annum. Basically the idea was to get rid of the waste water by open pond evaporation system after preliminary pre-treatment. The refinery designed three evaporation ponds to treat the discharged waste water. Each pond is 650 m in length and 420 m in width and of 2.2 m in depth. The ponds were sealed downward with plastic sheets to ensure seepage prevention. The total evaporation area was estimated at 800000 m^3 with a daily estimated evaporation loss of about 6800 m^3/day. However, the daily excess water was estimated at 4200 m^3. This water was used to irrigate a forestry project surrounding the Refinery. Small villages with thin population are scattered in the area and the inhabitants are mostly farmers and sheep herders. However some young men are hired as casual labours in the refinery and forestry project.

The objective of this study was to assess the impact and potential risks of disposed produced petroleum water (DPPW) on the ecosystem in the study area through assessing the quality of produced water effluent in different treatment stages and the impact of produced water on the soil and vegetation cover in the study area.

2. Study Site, Material and Methods

The research was conducted at the Khartoum Refinery Company in Sudan, about 70 kilometres north of the capital Khartoum and the Refinery is located 25 Km North-East of Al Gaily town on a semi-rocky-desert land 12 km from the river Nile.

The refinery is located in an area that had been classified as an arid area. The natural flora of the area has been described by Harrison and Jackson (1958) as desert scrub with sparse vegetation, characteristic of the semi desert zone of the Sudan. The annual amount of rains ranges between 0.0 and 200 mm, average rainfall of past years was 127.5 mm per annum and maximal annual rainfall is 147.5mm, maximum and minimum temperatures range from 45 – 25 C°. Average wind speed is 3.9m/s. and mostly it has a North direction in winter and south in summer and water table is 30m deep.

The subsoil consists of stiff or dense sand clay and silt sands in the top meter. In some areas the top soil layer consists of medium to coarse gravity sandy clay. The top soil layer is underlined by stiff to hard clayey sandstone which changes to weathered rocks with increasing depth of the boreholes. There are two valleys on both sides of the refinery that flow directly to the River Nile. The export crude oil pipeline from blocks (1) (2), 4, the railway line and Eltahdi Road all pass by the refinery, which occupies an approximate area of 9480, 000 square meters. The capacity of the refinery is 100,000 barrels of oil per day.

The waste treatment unit for the produced water is designed in modified way by collection of waste water and treated of alkalinity and acidity water to be neutralized, then skimming of oil from the water. This waste passes into biochemical unit for further treatment to get rid of the pollutant materials. After treatments water was used to irrigate forestry trees in an area of 300fed. Trees plantations are *Eucalyptus camadulensis* and were established in the year 2004 at different intervals till the year 2011.

Data collection from the study area included: 1) Water samples were collected from three waste water treatments bonds, (horizontal and vertical samples were taken from each pond). Samples were analyzed for pH, EC, Na, Ca, Mg; 2) Soil samples were taken, in 2011 from the same locations throughout the area irrigated by treated water (forestry project) and non irrigated area (as control). Two grid auger samples per plot to three depths (0-30), (30-60), (60-90) cm were taken every 100 m base of longitudinal transects in the irrigated area and were divided into four sites as follow: Site A: 8 years, site B: 4 years, site C; 1 years and site-D: from non-irrigated areas as a control. Soil electrical conductivity (EC_e), exchangeable sodium percentage (ESP) and sodium adsorption ratio (SAR) were determined to investigate the effect of treated water on soil salinity in the study area. 3) A survey and measurements of trees height and diameters to the breast in forestry project were done.

3. Results and Discussion

Results indicated that DPPW more alkaline and would increase in the ponds-1 and 2 of treatment and they decrease at pond-3 which was used to irrigate the forestry project. There was an increase in the percentage of some elements e.g. sodium, (table-1).

Table 1: Average parameters of the three water treatments stabilization ponds in Khartoum refinery.

Ponds	Sample	PH at25C^o	EC at25C^o Dm^{-1}	Na (ppm)	Ca (ppm)	Mg (PPm)
pond-1	H*	9.15	2088	240	27	9.605
	V*	9.11	2098	340	34	9.546
pond-2	H	8.81	1808	208	30	10.19
	V	8.81	1855	260	29	10.19
pond-3	H	7.52	894	112	27	7.321
	V	7.58	881	88	29	7.345
	Average	**8.496667**	**1604**	**208**	**29.33333**	**9.032833**

H: horizontal sample, V: vertical sample

According to the FAO guidelines for water quality for irrigation, the pH average values should be within the normal range 6.5 to 8.4, (Ayers, et al., 1994).

Differences in salinity between irrigated and non irrigated sites showed in Fig.1. The non irrigated site (D) had lower EC than irrigated sites (A, B, and C.) at all depths.

- The salinity as indicated by electrical conductivity (EC) of irrigated sites (I, II, and III.) increases with depths relative to non-irrigate site.
- The soil original was non saline by irrigation, its salinity increases throughout the soil depth.
- Soil that irrigation for year has lower salinity compared to sites that irrigated for 4 and 8 years.

Soil that irrigated for 8 years has lower salinity compared to 4 years indicated the washing of salt by irrigation.

Soil salinity started to increase at the first depth (0-30cm) and continued to decrease with depth [(30-60cm) and (60-90cm), respectively] in all irrigation durations, and that was clearly observed at the 4 years and 8 years irrigation durations. The EC at 4 years irrigation duration was high compared to the other sites at all depths. This high salinity in site-B was attributed to irrigation and low level of downward washing of the salt. Beside that there was a large open space as bare land without trees.

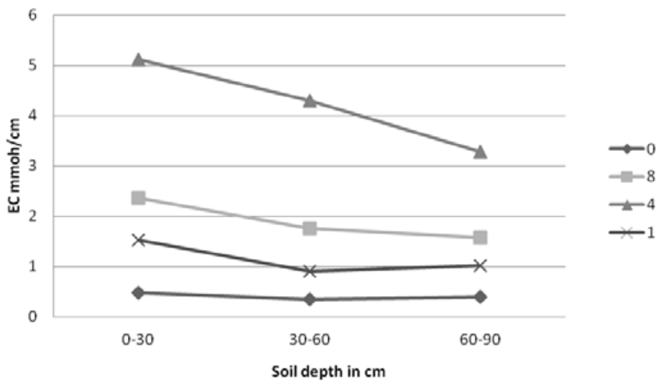

fig.1: Soil Salinty (EC) as function of irrigation duration at Algaily forestry
0=non irrigated, 1= irrigated for one year, 4= irrigated for four years
and 8= irrigated for eight years

Figure 2: Increase in exchangeable sodium percentage (ESP) with irrigation duration at the three sites (A, B, and C) with increase in irrigation duration.

The (ESP) at the non irrigated site recorded a lower value compared to the irrigated sites and the value of ESP recorded in site - A (8 years irrigation duration) was high at the second depth and decreased in the third depth.

Sodium adsorption ratio (SAR) showed a different trend; it started to decrease in the second depth and to increase in the third depth, except in site-A. Fig. 3.

Soil sodicity, as indicated by the exchangeable sodium percentage (ESP), increased at both site-A and B (irrigation duration of 4 and 8 years respectively). However, site –A showed a higher sodicity than site-B and there was the same pattern with salinity for the two sites, in decreasing with the depth.

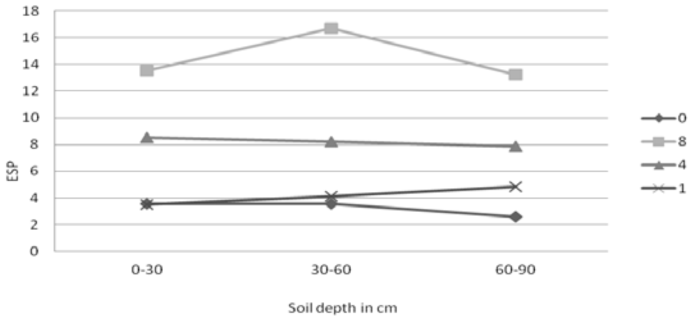

fig.2: soil exchangable sodum percentage pattern as a function ofof irrigation duration at Algaily forestry project, (0=non irrigated, 1= irrigated for one year, 4= irrigated for four years and 8= irrigated for eight years).

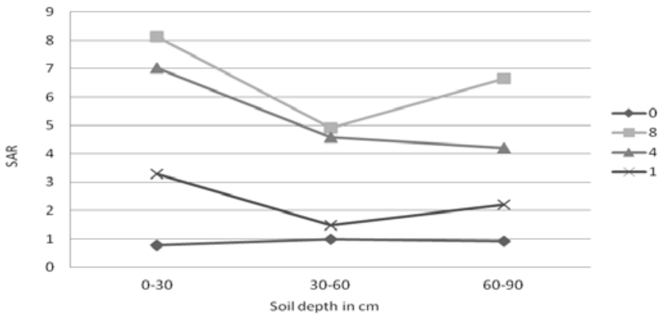

fig.3: soil sodium adsorption(SAR) as a function of irrigation duration at Algaily forestry, (0=non irrigated, 1= irrigated for one year, 4= irrigated for four years and 8= irrigated for eight years).

Normally, the soluble salts content in the soil was low, but low rain fall and high evaporation, natural vegetation clearance and high ground water table are in favour of salts an accumulation within the root zone (Mengel and Kirby 1987; Gorden 2006).

In the root zone, salts accumulate by two processes: upward movement of shallow water table The total amounts of the salts that accumulate in soil affect productivity, chemical and physical properties of the soil due to insufficient leaching (Stephen, 2002;Al-Amin,2009), especially the accumulation of soluble salts of sodium, magnesium and calcium which cause soil Stalinisation, this the process that leads to an excessive increase of water-soluble salts in the soil. Salinisation, also known as alkalisation or sodification, is often associated with irrigated areas where low rainfall, high evapotranspiration rates or soil textural characteristics impede the washing out of the salts which subsequently build-up in the soil surface layers. Irrigation with high salt content waters dramatically worsens the problem. (Gergely, 1995; 2013). A distinction can be made between primary and secondary salinisation processes. Primary salinisation involves salt accumulation through natural processes due to a high salt content of the parent material or in groundwater. Secondary salinisation is caused by human interventions such as inappropriate irrigation practices, e.g. with salt-rich irrigation water and/or insufficient drainage. (Rengasamy 2002; Barrett, 2003). According to this distinction the salinity in site-A and site-B belongs to the secondary type. The accumulation of salts, particularly sodium salts, is one of the main physiological threats to ecosystems. Generally, salinity negatively affects plant growth and that appears to be clearly in site- B in which there was a low number of trees with small size and a wide range of bare land with a high number of fallen trees per plot. The result of this study, indicate that as irrigation duration increased, there was an increase in soil salts content of EC, ESP, SAR especially in the sites which were irrigated for eight and four years and that indicate the a tendency to accumulate salts with increasing of irrigation duration within depths.

The study showed that the soil was affected by the type of treated water and the soil going on the way of sodicity. Also the was not a good washing of salts from this soil and that leads to accumulation of these salts at all three depths and these depths include the range of root zones of trees which could be affected by accumulation of salts with time. Generally, both soil salinity and sodicity were increasing relative to the non irrigated soils. The situation indicates that continuing irrigation with this water could develop non saline sodic soil. Sodicity will damage the physical prosperity particularly water movement. This finding supported by the general morphology of the plantation. Results from the survey and measuring of plants data indicated that there were more trees falling, dryer, burn, with more bare space area and shorter in heights and smaller diameters when irrigated with treated water than other tree plantations. This finding agree with (USA Staff 1953; Warrence et al., 2002) who reported that the salinity negatively affects plant growth, sodicity causes deterioration of the soil physical properties and both salinity and sodicity are land degradation processes. The study strongly recommends that stakeholders should develop risk-based corrective actions by enhance methods of treatment water to decease percentage of salts in irrigation water. Therefore, the final result would be decrease the impact of environmental pollutants from produced water in the area of oil production and industry.

References

Al-Amin, Nawal (2009) Effect of Irrigation on Soil Distribution Profile at Umjawasir Farm in the northern state-Sudan, U. of k. J. Agric. Sci.17 (2), 212-227.

Ali Elredaisy, S.M. (2010) Ecological Benefits of Bioremediation of Oil Contaminated Water in Rich Savannah of Plague, Upper Nile Area-Southern Sudan. 1:103.

Ayers, R.S. and Westcott D.W. (1994) Water quality for agriculture, Regional Water Quality Control Board Sacramento, California, USA FAO Irrigation and Drainage Paper 29 Rev. 1.

Barrett, E.G. (2003) The interaction between water logging and salinity in higher plants: Cause, consequences and implication. Plant and Soil 253, 35-54.

Beg, M.U., Al-Muzaini, S., Saeed, T., Jacob, P.G., Beg, K.R., Al-Bahloul, M., Al-Beg, M.U. (2003): Distribution Environmental Contamination and Toxicology.

Gergely, Toth (2012) Joint Research Centre-Institutes for Environment and Sustainability. European Communities, 1995-2013.

Jackson, J.K. (1958) Fung working plan for 1959-1968, for. Dep. (Sudan). For. Bull. 3, 71.

Johnson T. (2010) Staff Writer U.S. Deepwater Drilling's Future Updated: May 27.

Matrouk, K., Al-Obaid, T. and Kurian, A. (2001) Chemical contamination and toxicity of petroleum hydrocarbon in sediment from coastal area receiving industrial effluents in Kuwait. Ecotoxicol Environ Saf. 54, 47–55.

Mengal, K. and Kirkby, E.A. (1987) Principles of plant Nutrition. 4th edition. International Potash Institute. Bern, Switzerland.

Neff, J.C., Finlay J.C., Zimov S.A., Davydov S.P., Carrasco J.J., Schuur E.A.G. and Davydova A.I. (2006) Seasonal changes in the age and structure of dissolved organic carbon in Siberian Rivers and streams, Geophys. Res. Lett., 33, L23401.

Rengasamy, P. (2002) Transient salinity and subsoil constraints to dry land farming in Australian sodic soil; an overview. Australian Journal of Experimental Agriculture 42, 351-361.

Stephen, R. (2002) Irrigation Water Salinity and Crop Productivity. University of California, Division of Agriculture and Natural Resources. Publication 8066.

Suleimanov, R.A. (1995) Conditions of waste fluid accumulation at petrochemical and sediment from a coastal area receiving industrial effluents in Kuwait. – Archives of Processing Enterprises and Prevention of their harm to water bodies. Meditsina Trudai Promyshlennaia Ekologiia 12, 31–36.

USA Staff (1953) Diagnose and Improvement of Saline and Alkaline Soils. USA Salinity Laboratory Staff, USDA Agriculture Handbook No. 60, USDA Washington, D.C.

Analysing Ecosystem Services at Watershed Scale: Implications for Conservation in Upper Kikuletwa Sub-Catchment, Tanzania

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Abstract

Catchment forests perform myriad ecological functions including provision of ecosystem services. They are, however, increasingly degraded due to anthropogenic activities in such a way their capacity to regulate and supply watershed services is significantly dwindling. We carried out this study in order to identify and document ecosystem goods and services in Upper Kikuletwa Sub-Catchment, Tanzania. A structured questionnaire was administered so as to solicit socio-economic data. Qualitative data was collected through group focus discussions and formal and informal interviews. Statistical Package for Social Sciences was used to compare means and MS excel was applied to generate figures. T-test and one-way ANOVA was applied to test the variation between location and across villages. Wild fruits, vegetables, grasses, birds, mushrooms are the ecosystem goods available in the area. Ecosystem services encompass control of soil erosion, climate regulation, water flow regulation, production of hydroelectricity, water purification, etc. The reason for WTP was people's reliance on irrigated agriculture. We concluded

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that sustainable supply of ecosystem goods and services in depends largely on how forests and watersheds are conserved. Therefore, we recommend designing of a feasible PWS scheme that could ensure increased and sustainable supply ecosystem goods and services especially water flow for irrigated agriculture.

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1. Introduction

1.1. Background to the problem

Forest ecosystems and their multiple ecosystem services (ES) provide the fundamental basis for human well-being, society and economy (Costanza *et al.,* 1997; De Groot *et al.,* 2002; Landell-Mills and Porras, 2002) that are key to local and global development. The global community can only fare well if the functions and production capacity of forest and their associated ES are maintained (Aylward, 2005; Carpenter *et al.,* 2006; MEA, 2005). As the size of the human population increases, however, demand for ES is projected to increase at an alarming rate. In turn the sustainable conservation of forests and production of most ES is under threat and, in many places, in decline (Farraro, 2001; Brauman *et al.,* 2007; Ferraro, 2009; Ferraro *et al.,* 2002). Access to ES is also constantly reshaped under increasing commercial pressure on forests and land.

In recent years, there has been an outcry for the rapid decline of ES that watersheds used to offer in the past (Costanza *et al.,* 1997; De Groot *et al.,* 2002; Kremen, 2005; MEA, 2005). Similar situation have been witnessed in different parts across the globe where dramatic fall of ES have posed serious challenges to forests and watershed conservation (Kulindwa, 2005; Kulindwa *et al.,* 2006; Georgiou *et al*., 1997; Dixon, 1997). Growing population coupled with increasing human needs has resulted in greater demand for ES including supply of drinking water, water for industrial activities and energy production (hydro power production) and irrigated agriculture (Msuya, 2010; Notter, 2010; Lalika *et al.,* 2011; Ngana *et al.,* 2011). While the capacity of watersheds to provide ES has become erratic and increasing arithmetically, catchment forests and watershed degradation has been increasing exponentially.

ES especially water from catchment forests are vital for the wellbeing of human and natural environment, and are central to any economy in the world (Zoumides and Zachariadis, 2009). From an economic perspective, water resources are essential inputs to agriculture production and the global demand for water has increased over time with increasing population, rising incomes, and changes in dietary preferences (de Fraiture and Wichelns, 2010). Water shortages have posed strong challenges to catchment forest and watershed conservation. Overexploitation of forest areas potential for water conservation threatens the resource base on which irrigated agriculture depends (Falkenmarket *al.,* 2007).

Like elsewhere around the globe, catchment forests and watersheds in Upper Kikuletwa Sub-Catchment (UKSC) in Pangani River Basin (PRB) are currently facing a number of environmental problems most of which are related to deterioration of water flow and failure to recognize and value economic benefits of hydrological services they provide (Kulindwa, 2005; Turpie *et al.,* 2005). Research and previous studies on forest health conducted in PRB shows that between 1952 and 1982, catchment forest in PRB has been in tremendous decline (Newmark, 1998).

Problems related to catchment forests and watershed degradation have been tackled in a number of ways in Tanzanian. In Kibungo sub-catchment in the south-eastern Uluguru Mountains (UM), the government of Tanzania has developed the policy foundation for Payment for Environmental Services (PES) (Lopa *et al.,* 2012) by building on earlier consultancy studies (Kulindwa, 2005; Mwanyoka, 2005; Kulindwa *et al.,* 2006). CARE International and WWF Tanzania have jointly been implementing the Equitable Payments for Watershed Services (EPWS) project with special emphasizes on fair and equitable distribution of benefits accruing from the sale of ES to downstream users.

Payments for Watershed services (PWS) has also been extensively and successful been implemented in Latin America (e.g. Costa Rica, Bolivia, Ecuador, Columbia, Guatemala, etc), Mexico, USA and in Asia as means for rewarding guardians of catchment forest for their involvement in conservation initiatives (Ferraro, 2001; Ferraro and Kiss, 2002; Pagiola *et al.,* 2005; Wunder, 2007, Pagiola, 2008; Wunder *et al.,* 2008; Clements *et al.,* 2010). Despite the positive signs and success stories of PWS implementation across the globe, there is limited information on the available ES in UKSC. Moreover, mechanisms for rewarding upstream communities residing adjacent to watersheds are not known. We carried out this study in order to bridge the existing information vacuum. Findings of this study and subsequent policy recommendations will form the basis for the establishment of PWS in UKSC.

1.2. Theoretical Framework for the Study

Figure 1 presents the framework of analysis that guided our study. It is a hypothetical payment scenario where key players and beneficiaries of ES were expected to interact in a winwin situation. The framework demonstrates the prevailing situation in terms of water and money flows for a fair and feasible PWS scheme.

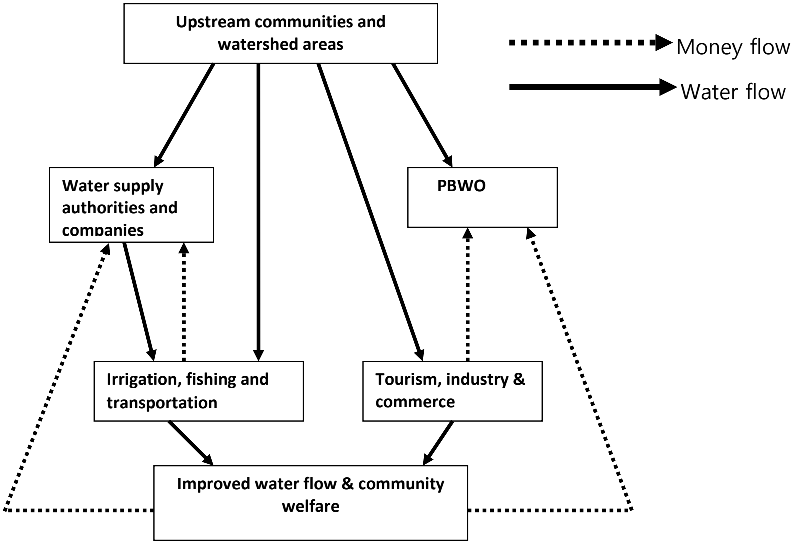

Figure 1: Analytical Framework for the study

Black arrows show water flowing downstream from catchment forests. In return water supply authorities and water basin offices (PBWO) receive money (dotted arrows) as payments for provision of the service. While the service (water) originates from watersheds upstream where the forest guardians (poor local communities) are found and play a significant role to conserve the watersheds, there is no any flow of resources (funds) to them. Making downstream water users understand the need for donating more funds for catchment forest conservation. Furthermore, this conservation mechanism is vital to the welfare of the upstream communities.

In this paper we present types of ecosystem goods and services; different approaches used in the restoration of catchment forest and watersheds in UKSC; willingness to pay for watershed services and returns to scale from irrigated agriculture. In addition, the paper recommends further action for the restoration of UKSC as single unit.

2. Materials and Methods

2.1. Location of the study area

The study was carried out in Upper Kikuletwa Sub-Catchment (UKSC) in Pangani River Basin Tanzania (Figure 2).

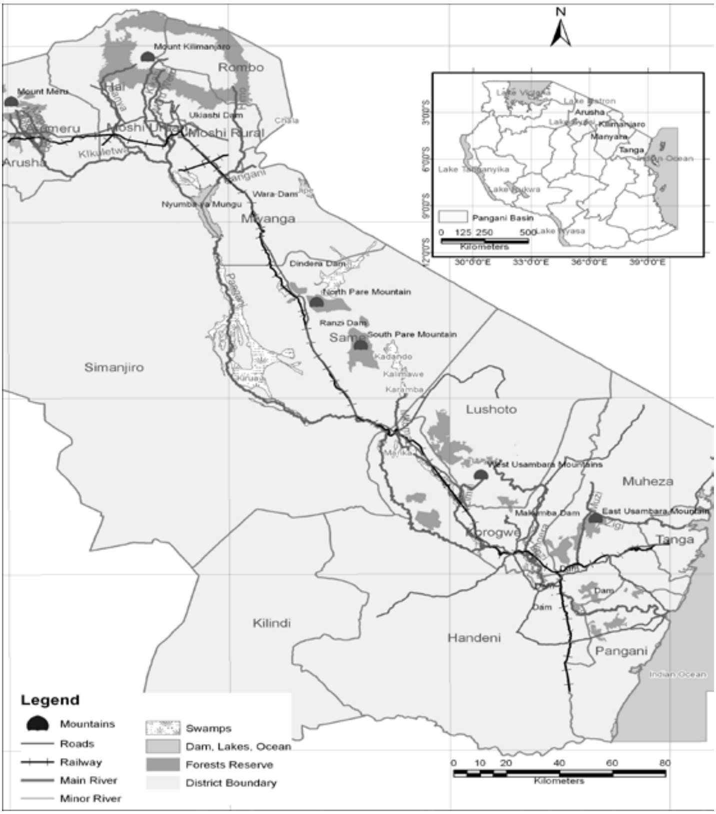

Figure 2: Location of the study area in Pangani River Basin, Tanzania

UKSC located in North-western part of Pangani River Basin which originates from both Meru and Kilimanjaro Mountains between 3^0 and 5^0 south of Equator. UKSC is (9,320 km^2) a source of Kikuletwa River and major tributaries of the river include Usa River, Makumira, Ngarenaro, Maji ya Chai and Tengeru. Irrigated agriculture is a key economic activity in KCSC because rainfall is erratic and unreliable. Average rainfall ranges from 1000 to 700 mm and varies with elevation. Precipitation decreases from the lower forest boundary down to the plains where it is less than 700mm annually. Temperature is closely related to altitude. It ranges from 15^0C to 30^0C with the minimum temperature 12^0C to 17^0C. Vegetation mainly riverine forest is found along Kikuletwa River and around water sources.

2.2. Data collection

Sampling procedure

A simple random sampling technique was used to select the sampling units in order to avoid bias. This technique allows selection of a sample from the entire population in such a way that every member of the population has an equal chance of being selected. The sampling frames for this study were the village registers containing the list of all household in the respective villages. In each village, households were randomly selected using a table of random numbers. The respondents were selected by matching their numbers in the register. For the purpose of this study, the study was divided into two parts. Western Kikuletwa where the majority are indigenous (Meru tribe) and Eastern Kikuletwa inhabited by emigrants who settled in the area after the downfall of plantation (sisal) economy. A total number of 242 respondents were interviewed, 112 and 130 in Western and Eastern Kikuletwa respectively (Table 1).

Table 1: Interviewed household heads

Region	Village	Total HH	Sample size	Sampling Intensity (%)
Eastern	Makiba	660	66	10
Kikuletwa	Kwaugoro	640	64	10
Western	Kikuletwa	640	64	10
Kikuletwa	Karangai	480	48	10
	Total	**2420**	**242**	**10**

Research phases

The study was divided into two parts. The first one involved reconnaissance survey with the aim of familiarizing the researcher with the study area and select study villages. Another key activity during phase one was to carry out questionnaires pre-testing. This is an essential step for socio-economic studies not only because it helps the researcher to check the questions for their validity and reliability but also is very important in identifying weaknesses, ambiguities and/or omissions before modifying the questionnaires to suit the prevailing environment for the main study.

Phase two involved questionnaire survey in the four villages (Table 1). A structured questionnaire containing both open ended and closed questions was the main tool for collecting socio-economic data. Questions were mainly on water utilization, types of water sources, methods of watershed conservation, type of crops irrigated, payment methods for water utilization, willingness to pay for water utilization, types of economic activities; other goods and services available PRB; just to name a few.

Data analysis

The 242 structured questionnaires were coded, cleaned and wherever applicable data from open-ended responses were categorized and transformed to enable further analysis. All quantitative analyses were performed using Statistical Package for Social Sciences (SPSS) version 16.0. Multiple responses were carried out to obtain frequency and percentages of responses and MS Excel was used to create figures.

To test crop production, two statistical methods for hypothesis testing were employed. While t-test was used to test the differences between yields in the two locations Eastern and Western Kikuletwa, one way ANOVA was employed to test and compare mean yields across villages.

3. Results

3.1. Ecosystem goods and services delivered by UKC

Figure 3 presents our results on ecosystem goods accrued in UKSC. In this study, goods are defined as use values that are used directly for consumption.

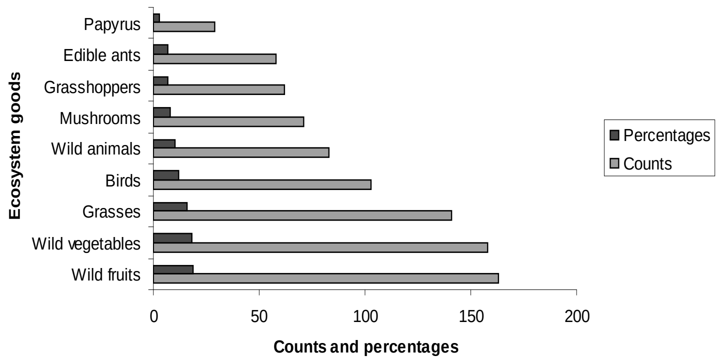

Figure 3: Ecosystem goods delivered by PRB, Tanzania
Source: Field data, 2012

In rural UKSC, local communities collect wild fruits from catchment areas either for sale or household use. During our survey we identified indigenous fruits such as *syzgium cumminii, ficcus thoningii,* etc. Local people engage in this kind of petty business as employment and income generation activity as well (Yemiru et *al*., 2010). According to personal communication Santoni Todayo (personal communication, 2012) in UKSC the return to scale from this kind of business was reported to be meagre to solve financial difficulties confronting many families. Other ecosystem goods include wild vegetable for domestic consumption, grasses for house construction, etc. With respect to ES, we identified a number of them as revealed in Table 2.

Table 2: Ecosystem services delivered by PRB, Tanzania

Ecosystem services	Frequency (n)	Percentage (%)
Soil erosion control	180	21
Climate regulation	153	19
Water flow regulation	159	19
Hydroelectric power production	108	13
Water purification	88	10
Hazard mitigation	81	10
Wild habitat	39	5
Spiritual and artistic inspiration	36	4

Source: Field data, 2012

Results in Table 2 shows that majority of the respondents (21%) indicated control of soil erosion as the ES they enjoy most in UKSC. This may be attributed to the fact that the area is mountainous, thus presence of natural vegetation (natural trees, herbs and grasses) slows down surface runoff and sediment load transport. Furthermore, soil erosion control enhances maintenance of productivity of farms (nutrient retention) and safeguarding water sources, river, streams and springs from siltation (De Groot *et al.,* 2002).

A good land cover (e.g. Meru Mountain, Arusha National Park, and other protected areas) regulates climate thereby playing a decisive role in reducing temperature and modifying rainfall. The presence of natural vegetation in this area improves microclimate condition and air purification for settlements, human and animal health and crop production. The cool weather condition attracts many tourists and has been termed as the "Northern Tourist Circuit" due to its favourable and good weather condition for tourism industry.

A good and intact land cover regulates surface runoff, ground and surface water discharge, environmental flow and water supply eventually. During our study we noticed that water from river Nduruma, Themi, Tengeru, Malala and presence of different water streams and springs testifies the role of catchment forest in water regulation (Costanza *et al.,* 1997). The catchment forest acts as sponge by regulating water flow gradually downstream. Water flowing downstream enhances economic undertakings such as irrigated agriculture, water for domestic uses, industrial activities, to name just a few.

3.2 Approaches used to conserve water sources

Four main methods were revealed i.e. retaining riparian vegetation (46%); tree planting (33%); prohibiting river bank cultivation (12%), and removing weeds and sediments (9%).

Table 3: Methods used in conserving water sources in PRB, Tanzania

Approaches	Counts (n)	Percentage (%)
Retaining natural vegetation	129	46
Tree planting	94	33
Prohibiting river bank cultivation	34	12
Removing weeds and sediments/muds	25	9

Source: Field data, 2012

From ecological point of view retaining natural vegetation and avoiding river bank cultivation are recommended techniques for optimizing multiple benefits of watershed function. Some of the retained trees in their natural habitats for watershed conservation include *Rauvolfia caffra*, *Melicia excelsa* and *Ficus sycomorus* and varieties of *herbs* species.

3.3 *Ecosystem services and irrigated agriculture*

Table 4: Crop yield and benefits from water uses in UKSC, Tanzania

Location	Village	Variable	Land size (ha)	Yield with irrigation (kg)/year	Yield without irrigation (kg)/year	Amount paid for irrigation water (Tshs)/year	Amount paid by association (Tshs)/year	Amount that people are WTP (Tshs)
Eastern Kikuletwa	Makiba	Mean	2	600	1549	4376.70	200000.00	7948.30
		Max.	7	8000	6000	36000.00		50000.00
		STD	1.3	1059	1137.4	5227.90		8338.10
	Kwaugoro	Mean	1.8	1124	569.2	3461.70	350000.00	6868.90
		Max.	10	10000	6000	15000.00		35000.00
		STD	1.6	1390	890.1	2625.40		5414.40
Western Kikuletwa	Kikuletwa	Mean	1	967	490	44250.80	220000.00	6578.10
		Max.	4	5000	7500	600000.00		50000.00
		STD	1	942	974.1	128528.90		7875.60
	Karangai	Mean	1	14067	756	12222.20	441000.00	10666.70
		Max.	4	32000	20000	36000.00		50000.00
		STD	1	4583	2909.4	7098.00		9744.25

Source: Field data, 2011

Average yield in irrigated and rainfed agriculture are presented in Table 4. These results revealed that irrigated agriculture seemed to outweigh yields under rainfed agriculture. Apparent reason for this variation in crop yield is that rainfall is not reliable and predictable due to a number of reasons including climate change. The highest amount that smallholder irrigators are willing to pay was Tanzania shillings 50,000/=.

Based on the findings presented in Table 4, we carried out one-way ANOVA in order to test whether the average yields for irrigated crops were significantly different between the two locations and across villages. Findings are summarised in Table 5.

Table 5: Comparison of average yield for different locations in UKSC, Tanzania

Location	Mean + SD	t and f-value
Eastern Kiluletwa	966.1 $\pm$ 1195.8	0.45 NS
Western Kikuletwa	882.8 $\pm$ 2628.8	
Villages	**Means + SD**	**t and f-value**
Makiba	1085.7 $\pm$ 1189.1	0.115 NS
Kwaugoro	846.5 $\pm$ 1195.4	
Kikuletwa	730.6 $\pm$ 983.9	0.985 NS
Karangai	1083.1 $\pm$ 3840.8	

F - value = 0.922; P - value = 0.43; NS = Non Significant (i.e. P > 0.05)

Source: Field data, 2012

Findings in Table 5 revealed that there was no significant different (P = 0.45) in crop yields between Eastern and Western Kikuletwa. With respect to yields between and across villages we found no significant different too. Similarly, ANOVA results between the two locations indicated no significant variations in crop yields.

4. Discussions

Ecosystem goods presented in Table 3 typifies rural phenomenal and village scenario where local communities harvest these nutritious non-timber forest products (NTFP). Wild fruits, vegetable and mushrooms are readily available ecosystem goods that are harvested freely in the wilderness. In UKSC these NTFP not only support the community wellbeing, but they also plays a key role in income generation (MEA, 2005). Thus, initiatives aiming at sustainable conservation against environmental degradation and climate change are key to sustainability. It is, therefore, high time to put emphasize on conservation of these ecosystem goods especially in areas where majority are poor and reliant on natural resources (Egoh *et al.,* 2007; 2011; 2012). ES displayed in Table 2 depend on each other and sustainability of one ES relies on how other ES are utilized and managed. For instance water regulation that enhances water flow for irrigation, power production (HEP), industrial purposes, and domestic uses depends largely on how UKSC is conserved to control soil erosion and regulate climate. A well conserved catchment forest acts as sponge by releasing water gradually and modifying climate (Lalika *et al.,* 2011). Once a catchment forest is degraded beyond repair, it implies that other ES such as water purification, hazard mitigation, wild habitat maintenance are compromised. For instance, once UKSC is sustainably conserved, the local communities most of which are poor will be able to enjoy the benefits from therein, and improve their welfare as well. Other multiple benefits will be indirectly realised as such. They, according to Egoh *et al.* (2008), include maintenance of a favourable climate, both at local and global scales, which in turn are important for, among others, human health, crop productivity, recreation and even cultural activities and identity.

Water regulation influences forest ecosystems on the regulation of environmental flows (Costanza *et al.,* 1997; de Groot *et al.,* 2002). Thus, the capacity of a catchment forest or watershed to perform this essential ecological function depends largely on how local communities utilize the resources from therein. According to Costanza *et al.* (1997), ES associated with water supply relate to the consumptive use of water by households, agriculture and industry. Local communities in UKSC have been exploiting unsustainably, thereby threatening future water supply. Consequently, water for irrigation and other domestic uses for instance, is nowadays compromised contrary to the past (Kulindwa, 2005). Thus striking the balance in water regulation is vital because too little as well as too much surface runoff can cause serious problems (Costanza *et al.,* 1997). A clear example is the excessive water flow that culminated in land slide in Same District in Eastern Arc Mountains along PRB, Tanzania two years back.

Retaining natural vegetation has been a key approach for conservation of nature since time immemorial. Protected areas where catchment forest and watersheds a found, the ideal conservation approach is *in situ* conservation. We found similar scenario for UKSC where conservation of catchment forest within their natural environment was preferred over other methods. This could be a key to the revival of water supply and environmental flow. Ecologically, advantages are many as this approach would enhance realisation of multiple ecological and socio-economic ES including conservation of ecological diversity and community wellbeing.

The absence of significant variation (difference) in crop yield (Table 5) denotes similarities in production potential of the two locations and across villages. The difference in crop yield just by one bag of 100kg and/or below in some instances is quite small. Thus, water which is an important ES for irrigation should be managed equally to boost agriculture productivity for community wellbeing. Machethe *et al*. (2004) reported similar findings that irrigated agriculture plans should include water regulation an important ES for poverty alleviation directives.

5. Conclusions

The study has indicated that ecosystem goods and services delivered by UKSC are mainly regulating and provisioning. While wild fruits and vegetables were reported to be the preferred ecosystem goods in UKSC, ES that preferred by majority of respondents are soil erosion control, climate regulation, water flow regulation and hydroelectric power production. In some instances, it was difficult to draw a line to demarcate ecosystem goods viz-a-viz ES due to their close complementarities. Generally, provisioning and regulating categories are the ecosystem goods and services found in UKSC and developing countries at large. And this calls for integrated approach for their conservation and restoration of catchment forest in the study area. Water flow regulation and water supply enhance irrigated agriculture through the provision of water for crop production. Results from a comparative analysis through t-test and one way ANOVA indicated non-significant variation in crop yield between Eastern and Western Kikuletwa and across villages in UKSC. Similarly, human being dependency on rainfed agriculture is a typical phenomenon in UKSC as is the case for majority of small holder farmers in less developed economies. Furthermore, the capacity of UKSC to provide goods and services sustainably depends on how the ecosystem good and services are utilized and managed. In the context of above remarks, we propose that any conservation intervention should be geared towards restoration of UKSC as a single unit at an integrated and holistic approach by bringing together all interested parties.

Acknowledgement

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References

Aylward, B. (2005) Towards watershed science that matters. *Hydrological Processes* 19(13), 2643 – 2647.

Brauman, K.A., Daily, G.C., Duarte, T.K. and Mooney, H.A. (2007) The Nature and

Value of Ecosystem Services: An Overview Highlighting Hydrologic Services. *Annual Review of Environment and Resources* 32, 61–63

Carpenter, S.R, De Fries, R., Dietz, T., Mooney, H.A. and Polasky, S. (2006)

Millennium Ecosystem Assessment: research needs. *Science* 314, 257–58

Costanza, R. et al. (1997) The value of the world's ecosystem services and natural capital. *Nature* 387, 253–260.

Clements, T., John, A., Nielsen, K., An, D., Tan, S. and Milner-Gulland, E.J., (2010) Payments for biodiversity conservation in the context of weak institutions: comparison of three programs from Cambodia. *Ecological Economics*, 69, 1283–1291.

De Groot, R.S., Wilson M.A. and Boumans, R.M.J. (2002) The dynamics and value of ecosystem services: Integrating economic and ecological perspectives. A typology for the classification, description and valuation of ecosystem functions, goods and services. *Ecological Economics* 41, 393 – 408.

Dixon, J.A. (1997) Analysis and management of watersheds. *The Environment and Emerging Development Issues* 2, 371–398.

Egoh, B.N. et al. (2012) An African account of ecosystem service provision: Use, threats and policy options for sustainable livelihoods. *Ecosystem Services* 2, 71–81.

Egoh, B.N., Reyers, B., Rouget, M., Richardson, D.M. (2011) Identifying priority areas for ecosystem service management in South African grasslands. *Journal of Environmental Management* 92, 1642–1650.

Egoh, B.N. et al. (2008) Mapping ES for planning and management. *Agriculture, Ecosystems and Environment* 127, 135–140.

Egoh, B.N. et al. (2007) Integrating ecosystem services into conservation assessments: a review. *Ecological Economics* 63, 714–721.

Falkenmark, M., Finlayson, M., Gordon, L. (2007) Agriculture, water and ecosystems: avoiding the costs of going too far. In: Molden, D. (Ed.), Water for Food, Water for Life: A Comprehensive Assessment of Water Management in Agriculture. Earthscan and International Water Management Institute, London and Colombo.

Ferraro, P.J. (2009) Regional review of payments for watershed services: Sub-Saharan Africa. *Journal of Sustainable Forestry* 28, 525–550.

Ferraro, P.J. (2001) Global habitat protection: limitations of development interventions and a role for conservation performance payments. *Conservation Biology* 15, 990–1000.

Ferraro, P.J. and Kiss, A. (2002) Direct payments to conserve biodiversity. *Science* 298, 1718–1719.

De Fraiture, C. and Wichelns, D. (2010) Satisfying Future Water Demands for Agriculture. *Agricultural Water Management* 97, 502–511.

Georgiou, S., Whittington, D., Pearce, D., Moran, D. (1997) Economic Values and the Environment in the Developing World.

Kremen C. (2005) Managing ecosystem services: what do we need to know about their ecology? *Ecology Letters* 8, 468 -479

Kulindwa, K., Ikiara, M., Chande, A. and Milly, N. (2006) To Conserve or to Convert the Lake Victoria Basin Wetlands: An Economic Valuation of Mara Wetland. Research report submitted to VicRES.

Kulindwa, A.A. (2005) Payments for Environmental Hydrological Services. Policy Briefs Water Resources Management in Pangani River Basin Tanzania. Economic Research Bureau, University of Dar es Salaam. Issue No 2 October 2005.

Lalika, M.C.S., de Deckere, E. and Ngaga, Y.M. (2011) Payment for Water Services as Basis for Natural Resource Management: Experience from Pangani Basin Tanzania. In: (Editors Anderson K., Okeyo-Owur, J.B. and Hezron, M.), Towards Implementation of

Payment for Environmental Services (PES). BOD Publishers, London.

Landell-Mills, N. and Porras, I. (2002) Silver Bullets or Fools' Gold?: A global review of markets for forest environmental services and their impact on the poor. International Institute for Environment and Development, London, UK.

Lopa, D. et al. (2011) Towards operational payments for water ecosystem services in Tanzania: a case study from the Uluguru Mountains. *Oryx* 0(0), 1 – 11.

Machethe, C.L. et al. (2004) Smallholder Irrigation and Agricultural Development in the Olifants River Basin of Limpopo Province: Management Transfer, Productivity, Profitability and Food Security Issues. Report to the Water Research Commission on the Project ''Sustainable Local Management of Smallholder Irrigation in the Olifants River Basin of Limpopo Province''. Water Research Commission, Pretoria.

MEA. (2005) Millennium Ecosystem Assessment. Ecosystems and Human Well-Being. Synthesis. Island Press, Washington, DC.

Miranda, M., Porras I.T. and Moreno, M.L. (2003) The social impact of payments for environmental services in Costa Rica. *Markets for Environmental Services* 1. IIED, London.

Msuya, T. S. (2010) Developing Integrated Institutional Framework for Sustainable

Watershed Management in Pangani River Basin, Tanzania. Thesis for Award of PhD Degree of Sokoine University of Agriculture, Morogoro, Tanzania.

Mwanyoka, I.R. (2005) Evaluation of community participation in water resources

Management: The case of the East Usambara Biosphere Reserve, Tanzania. Research report submitted to UNESCO MAB young scientists programme.

Newmark, W.D. (1998) Forest area, fragmentation, and loss in the Eastern Arc Mountains: implications for the conservation of biological diversity. *Journal of East African Natural History* 87, 1 – 8.

Ngana, J. et al. (2010) Managing water resources in dynamic settings: A multi-level, multi-stakeholder perspective. *In:* Hurni H, Wiesmann U, editors; with an international group of co-editors. Global Change and Sustainable Development: A Synthesis of Regional Experiences from Research Partnerships. Perspectives of the Swiss National Centre of Competence in Research (NCCR) North-South, University of Bern, Vol. 5. Bern, Switzerland: *Geographica Bernensia*, 91–106.

Notter, B. (2010). Water-related ecosystem services and options for their sustainable use in Pangani Basin, East Africa. (PhD Thesis). Bern, Switzerland: Institute of Geography, University of Bern.

Pagiola, S., (2008) Payments for environmental services in Costa Rica. *Ecological Economic,* 65, 712–724.

Pagiola, S., Arcenas A. and Platais, G. (2005) Can payments for environmental services help reduce poverty? An exploration of the issues and the evidence to date from Latin America, *World Development* 33, 237-253.

Pagiola, S., Bishop, J. and Landell-Mills, N. (2002) Introduction. *In*: Pagiola, S., Bishop, J. and Landell-Mills, N. (Eds.) Selling Forest Environmental Services: Market-based Mechanisms for Conservation and Development. Earthscan, London, UK.

Turpie, J.K., Ngaga, Y. and Karanja, F. (2005) Maximising the value of water resources. Policy briefs for water resource management in Pangani River Basin-Tanzania. Issue No 1.

Zoumides C. and Zachariadis T. (2009) Irrigation Water Pricing in Southern Europe and Cyprus: The effects of the EU Common Agricultural Policy and the Water Framework Directive. *Cyprus Economic Policy Review* 3 (1), 99-122

Wunder, S. (2007) The efficiency of payments for environmental services in tropical conservation. *Conservation Biology* 21, 48–58.

Wunder, S., Engel, S. and Pagiola, S. (2008) Taking stock: a comparative analysis of payments for environmental services programs in developed and developing countries. *Ecological Economics* 65, 834–852.

Managing and Developing Resources Available in El Ain Reserved Forest for Eco-Tourism, North Kordofan State, Sudan

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Abstract

The study was conducted in Elain area, North Kordofan during 2008 – 2011, in three administrative units, where four villages were selected. It investigated the possibility of achieving maximum utilization of natural resources available and development of reserved forest into natural tourist park. This process implies inventory of natural and human resources, investigating awareness and attitudes of local communities and relevant governmental institutions. Primary data were collected using Two-Stage Random Sampling from tourist and non-tourist villages. Two tourist villages (28%) and two non-tourist villages (20%) were selected. In each village 15 questionnaires were distributed to randomly selected respondents (60 persons). Besides personal observations during field survey, a questionnaire was distributed to key-informants in the concerned governmental institutions. SPSS program was used for data analysis. Current situation of Elain area was analyzed for strengths, weaknesses, opportunities and threats (SWOT ANALYSIS) and compared to other natural reserves at different levels; locally and nationally, regionally. The study concluded that Elain forest with its natural biotic variations, attractive recreation facilities; wide range of cultural attitudes and folkloric activities can be developed into natural tourist park.

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1. Introduction

The history of conservation areas and national parks in Sudan has always been closely linked to the historical and political evolution of the country. The wide variety of ecosystems and vegetation types in the Sudan is reflected in its fauna. A list of 52 major wildlife species and their distribution in Northern Sudan was produced (WCCGA, 2004). Also a list of 83 major wildlife species and their distribution in 19 protected areas in the Sudan. It is reported that, there are 871 species of birds in the Sudan. The distribution atlas of Sudan's birds included information on 931 species. There is only limited information on amphibians, reptiles and insects in the Sudan. About twenty-six areas are gazetted and declared protected areas and an equal number of areas are proposed. Some of the areas were gazetted as far back as 1936, while others were relatively recently established such as *Wadi Howar* National Park in 2002 and Jebel Hassania in 2003 (WCCGA, 2004). In Elain forest, Muneer (2009) identified species were classified according to their growth habits into 35 trees, 13 shrubs and 2 woody climbers. Four species were exotic. Five woody species were reported for the first time in the area. They were *Ficus salicifolia*, *Boscia salicifolia*, *Ximenia americana, Cordia africana,* and *Capparis tomentosa*. Five species were considered endangered; *Boswellia papyrifera, Sterculia setigera, Sclerocarya birrea, Lannea fruticosa, Albiziza anthelminthica* (Eltahir, 2009). This means that the micro- climate of the forest as well as it environment enhance the diversity which later attract the people for visits and tourism.

2. Objectives

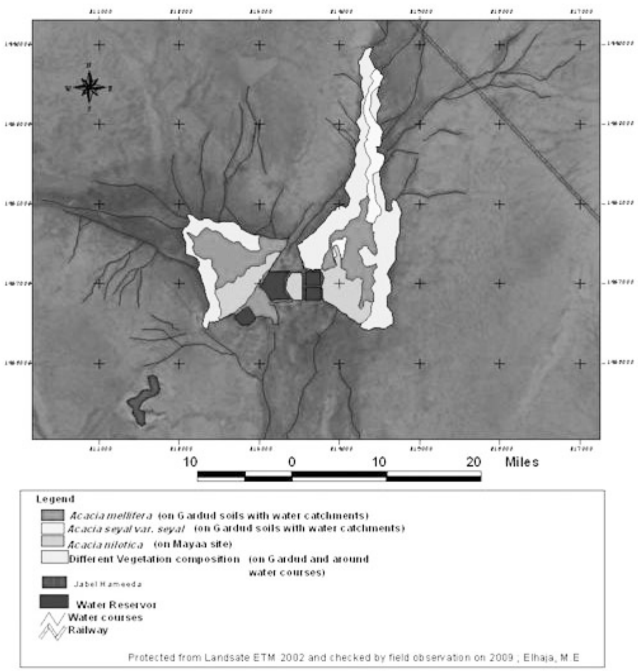
The general objective of this study is to assess available resources for management and development of Elain Reserved Forest for eco-touristic purposes.

Specifically the study aims to

- investigate possibility of achieving maximum utilization of natural resources available and development of the reserved forest into natural tourist park.
- investigate awareness and attitudes of local communities as well as relevant governmental institutions.

3. Study area

El Ain Reserved Forest, North Kordofan State (12° 52 _ -13° 04 _ N and 30° 10 _ - 24°E). Under semiarid, annual rain fall between 200-250mm. MAT is 27° C, non cracking soil, locally known *gardud*, of poor Acacia woody vegetation namely *Acacia nilotica, Terminalia brownii, Balanites aegyptiaca* and *Adansonia digitata* are also found.



El Ain Vegetation Cover and Water Resources Map 2009

According to Tagelsir (2005), Elain forest is characterized with high density of trees and shrubs, diversity, green, calamity and attractive seen. In the forest and the surrounding bufferzone there are hills and mountains of great beauty values such as Kordofan mountain, Hamdella mountain and Hameeda mountain in addition to some historic and ethic places. The forest also encompasses forest reservoir which is considered the main source of Elobeid town. The diversity of tribes with their different customs and traditions acquired the area great important where many people from Elobeid and the neighboring area come to visit.

4. Data Collection

Primary and secondary data were collected for achievement of study objectives. The primary data were collected using the Two-Stage Random Sampling from villages. In each village 15 purposively designed questionnaires were distributed to randomly selected respondents, who make a total of 60 persons representing 22.6% of the total population in selected villages. Besides personal observations during field survey, another type of especially designed questionnaire was distributed to key-informants in relevant governmental institutions. The so-called SPSS program was used as a statistical package for analyzing the study data. The current situation of Elain area was analyzed for strengths, weaknesses, opportunities and threats (SWOT ANALYSIS) and compared to other natural reserves at different levels; locally and nationally (Sudan), regionally (Africa), internationally (Europe and East Asia) and at the Arab World level. The descriptive statistical method was applied as a tool for data analysis and presentation.

5. Results and discussion

The study researched many important results that can give great push towards the basic idea of developing Elain forest into a natural tourist reserve. The forest is found to be characterized with a wide natural biotic variation of animals and plants, besides availability of attractive recreation facilities and scenes, plus hills and mountains around the area. Being a high well-stocked forest free of pollution, Elain forest is very close to the densely populated Elobeid town; the capital of North Kordofan State.

Elain area is a secure area with almost no conflicts between stakeholders and covered with audiovisuals information media. The area has different kinds of livestock and wildlife with few carnivorous types. At the same time the area is characterized with availability of healthy water sources suitable for drinking, and the transport is easy to and from the area and within the area.

With respect to community of the area, almost people are nomads, moving regularly in dry and wet seasons. Different tribes in the area have a wide range of cultural attitudes and tribal folkloric activities, besides other different kinds of local behaviors and hobbies. The regular on weakly-basis markets reflect cultural activities and facilitate bilateral exchange of resource use and local products. All population in the area, as well as staff of relevant governmental institutions are in favor of the thought aiming towards development of natural resources available in the area into a natural tourist reserve and they are not against foreign visiting tourists to the area. Generally it can be concluded that natural and human resources available in the area can be developed to achieve the main objective of the study.

Table 1: Stakeholders benefited from the forest

Stakeholders	Frequency	Percent
Local people	40	66.6
State	3	5
Herders	1	1.7
Local people, state and herders together	13	21.7
Visitors	3	5
Total	**60**	**100%**

Table 1 showed that the majority of benefited stakeholders are local people. In addition, 98.3% appreciated the idea of developing Elain to a touristic area (table 2). This is a good indicator to get their opinions and perspectives toward the developing of the forest and the area as well into a touristic site.

Table 2: Possibility of developing Elain to a touristic area

Stakeholders' decision	Frequency	Percent
I agree	59	98.3
I don't agree	1	1.7
Total	**60**	**100**

Table 3: Visiting seasons for touristic purposes

Visiting seasons	Frequency	Percent %
Summer	**32**	**53.3**
Autumn	**24**	**40**
Winter	1	1.7
Holidays	1	1.7
No visits	2	3.3
Total	**60**	**100**

Referred to table 3, summer and autumn are the most preferable month for visitors. During summer (the hottest season in Elobied) people like to refresh themselves by having small sightsee in Elain area. However, in autumn the area attract the people by its splendor nature.

Table 4: SWOT Analysis of the current situation of Elain area

Strength	**Weakness**
- Fauna and flora biodiversity - Security and less conflicts - Frequent visits for touristic purposes - Socio-cultural diversity - Government support for environment protection - Far from source of industrial areas - and pollution sources - Nearest forest to Elobied town	- High rainfall amount - Occurrence of seasonal streams valleys - Weak infrastructure - Low finance - Water shortage in summer - Low technical and capacity building among respondents - Drought spells of the year 1984 - Low number of foreign visitors

Threats	Opportunities
- Illicit cut for trees and shrubs - Overgrazing illegal poaching - Fires	- Attractiveness of the area - Beauty mountains - Availability of tourism potentials - F easibility of mobility except in rainy season - Containing the largest water reservoir in western Sudan - Clay soil and Gardud sore water - Diversified and Peaceful wild life

6. Conclusion and recommendation

The study concluded with recommendations that are expected to serve the main goal of achieving maximum utilization of resources available in the area and its conservation for the benefits of future generations and scientific research. The importance is highly needed from all stakeholders to promote the situation to the global standard level. Strict protection is needed and people orientation should be adopted. Natural and human resources available can be developed into natural tourist park. People and staff of governmental institutions accept basic idea of the study.

References

Eltahir, M.E.S. (2009) Assessment of Woody Species Diversity in Elain Area, North Kordofan, Sudan. M.Sc. Tropentag, 2009, Hamburg Germany

Eltahir, M.E.S. (2011) Management of Protected Areas, Wildlife and Tourism, case of ElDinder National Park, Seminar Paper, TU-Dresden. Higher Council for Environment and Natural Resources

Nimir, M.B. (1983) Wildlife conservation in the arid zone of the Sudan, Wildlife Research Division, Khartoum, http://www.unu.edu/unu press/unupbooks/80044e/80044e05.htm

Tagelsir, U. (2005) Proposal for Tourism in El Ain Forest Reserve, Forest National Corporation. UNDP/GEF Project SUD/98/G41 and SUD 00/014. 2004 management plan for Dinder National Park Sudan

Wood Production

Socio-Economic Characteristics of Acquisition and Consumption of Household Biomass Energy. A Case Study of Sinnar State, Sudan

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Abstract

The objective of this research was to investigate patterns of household energy, estimate periodic mean consumption and examine the effects of related socio-economic characteristics on household domestic energy consumption in Sinnar State, Sudan. The research addressed households in Singa, Elsouki and Abuhojar localities. Primary data was collected by use of structured questionnaires completed during a field work carried out during 2010. A sample size of 400 households was used and samples were distributed between localities and villages according to their relative population densities. Quantitative data were processed and analyzed using Statistical Package for Social Science (SPSS). Descriptive statistics and analysis of variance were applied to compare means of quantitative variables of the data. The results indicated the high dependency of households on wood products in energy use where 95.0% and 93.7% of households depends on firewood and charcoal, respectively. Results illustrated that households met their demand for firewood through free collection while that of charcoal is met by direct market purchases. Per capita mean daily consumption rate was 0.86 kg and analyses showed significant differences ($\alpha = 0.05$) in mean quantities of firewood collected per day between Abuhojar and each of Singa and

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Elsouki localities, and in distance walked where household members walk longer distances in Elsouki relative to other localities.

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1. Introduction

Energy is a key-resource to economic development and is required to be available continuously and in adequate amounts. Also, it is expected to be affordable and environmentally friendly (Blum and Legey, 2012).In the absence of affordable modern fuels and electricity, 90% ofthe Sub-Saharan African population relies on traditional fuels for cooking, heating and lighting (Adkins et al., 2012). The utilization of biomass has attracted great attention worldwide because of its recognized role in reducing CO_2 emissions by partly replacing fossil fuels. The residential sector accounts for one-fifth of global energy consumption, resulting from the requirements to heat, cool, and light residential dwellings. It is therefore not surprising that energy efficiency in the residential market has gained importance in recent years (Brounen et al., 2013).

The primary fuel resource to which African villagers have affordable, ready access is biomass, either fuel wood or farm residue (World Bank, 1996).Dependence on traditional biomass for household energy is most prevalent among the rural poor in sub-Saharan Africa and south Asia. Typically solid biofuels are burned in open fires or simple metal stoves, which are often inefficient and highly polluting compared to fuels like kerosene, cooking gas, or electricity (Bailis, 2009). Almost all African countries still rely on wood to meet basic energy needs. At aggregated level, woodfuels share an estimated 60% to 86% of African primary energy consumption, except in North African countries and South Africa, where the woodfuel contribution is less significant. Moreover, woodfuel use accounts for 90 to 98 % of residential energy consumption in most of sub-Saharan Africa (FAO, 1999).

Patterns of domestic energy use are closely linked to agro-climatic, socio-economic conditions such as the level of the user's living standards, family size, education, farm area per rural household and forest area per household. It is also influenced by government policy, which affects the inequity in fuel and equipment availability among different income groups (Cai and Jiang, 2008). Brounen et al. (2013), referring to the Netherlands, report that the level of education is the most important household characteristic explaining energy literacy—making the optimal choice when considering an investment in more energy-efficient equipment.

Within the family, women are generally the most concerned by fuel wood issues since they devote a lot of their time to fuel wood gathering and cooking tasks (FAO, 1999). The greater time needed for gathering, transporting and using these fuels also reduces the prospects for using this time in more productive work or education. In addition, as women and children are more likely to suffer from many of these adverse effects, the issue has an important gender and equity dimension (Pachauri, 2004). However, there is rather broad evidence from a variety of Asian and African countries that both men and women collect, and men may even be the primary collectors (Cooke et al., 2008).Charcoal production and marketing on the other hand tend to be more formalized and male-specific, helping to provide jobs and substantial revenue for rural and urban people (FAO, 1999).

Household consumption of energy for space heating and cooling, lighting, appliances, transportation, and other energy services is a key driver of national energy demand (O'Neill and Chen, 2002). The pivotal question remains why energy use of households keeps rising. On the one hand, macro-level factors i.e. technological developments, economic growth, demographic factors, institutional factors and cultural developments, contribute to this increase. In turn, these factors shape individual (viz., micro-level) factors such as motivational factors (e.g. preferences, attitudes), abilities and opportunities (Abrahamse et al., 2005). A number of demographic factors such as population size, age structure, and levels of urbanization have potentially important direct and indirect influences on household demand (O'Neill and Chen, 2002).As the economy progresses, commercial energy consumption and electricity consumption become predominant and traditional biomass energy consumption decreases (Bildirici, 2013).However, other demographic variables could be important as well are the influence of aging, changes in lifestyles, and changes in household size and composition on energy use. Household size appears to have an important effect, not only on energy use per household but on a per capita basis as well, most likely because of the existence of substantial economies of scale in energy use at the household level. The principal source is the sharing of public goods such as space, home furnishings, transportation, and energy. The sharing of energy services results in lower per capita energy use in larger households, all else equal. Thus as populations age and average household size declines, the loss of economies of scale can be expected to increase per capita energy use more than would otherwise be expected (O'Neill and Chen, 2002). The ownership of dwelling is also an indicator of standard of living (Ouedraogo, 2006). Couture et al. (2012) conclude that household wood energy consumption is affected by its own price. Vaage (2000) shows that energy consumption is largely influenced by energy powered devices such as heating, cooking and washing equipment. Socio-economic benefits of biomass energy consumption can be identified as a significant driving force in increasing the share of bioenergy in the total energy supply (Bildirici, 2013).

The factors that most likely affect fuel choices vary by location, financial circumstances and household preferences. Therefore, the energy choices of consumers with different income and location should be assessed separately in energy policy analysis (Ekhlom et al., 2010). In general, according to different or similar natural conditions, socio-economic backgrounds, political purposes and technical support, similar domestic energy use patterns have been emerged in the developing countries all over the world such as India, Sri Lanka, Bangladesh, Sudan, Nigeria and China (Liu et al., 2008).

Firewood collection and wood gathering has become a fulltime occupation. In distance this responds up to half a day's walk away, or more. This loss of time places a huge constraint on other activities that are necessary to support the family (FAO, 2001).This process induces tremendous eco-environment degradation, such as deforestation, soil erosion and desertification and some other health impact and social impact, such as time occupation and less education (Liu et al., 2008). Traditional fuels as presently used have inherent disadvantages. Collection is arduous and time-consuming, combustion is difficult to control and cooking methods capture only a fraction of the fuel's available energy (Joon et al., 2009).

Even though rural households often have an easy access to traditional forms of energy - firewood, charcoal and agricultural residues - to fulfill their basic energy needs, these fuels carry adverse effects, such as emissions of particulate matter that are harmful to health, deforestation and environmental degradation (Pachauri, 2004). The heavy dependence on biomass threatens the health and future of domestic forests (Omer, 2009).

The management of wood fuel resources and demand should be considered a major issue in energy planning processes in Africa. Wood fuel consumption is a major contributor to total wood removal, accounting for around 92% of total African wood consumption and contributing to greenhouse gas emissions. Wood fuel use is therefore a major local and global environmental issue in Africa, and should be fully integrated into forestry planning and environmental protection processes (FAO, 1999). Fuel wood collection places a substantial time-labor burden on families, particularly women, and can place additional pressure on local forest resources, particularly in places where fuel wood is scarce(Adkins et al., 2012).

The major use of wood in Sudan continued to be for energy which amounts to 65–80% of the total wood consumption in the country, with the major part of fuel wood being used in rural areas as raw firewood (Gaafar, 2011). Households are major energy consumers. In 1995, these consumed 92 % of the total biomass consumption. From electricity this sector consumed 60 % of the total consumption, and 5.5 % of petroleum products (Omer, 2002).The Sudan presently derives over 80% of its total energy use from wood and charcoal, and the highest consuming sector is households (FAO, 2007). The unsustainable extraction of fuel wood is a major problem in northern and central Sudan, as well as in refugee and displaced persons camps all over the country and particularly in Northern Darfur (Gaafar, 2011).

The main objective of this study is to investigate pattern of household domestic energy use and to analyze socioeconomic factors that influence household collection and consumption of wood fuel in Sinnar State, Sudan.

2. Materials and methods

2.1. Study area

Sinnar State lies between latitudes 11° 45´ N and 14° 03´ N and longitudes 32° 28´E and 35° 43´ E with an area of 4.076 million hectares (Fig.1). Total population of the state is 1,285 million, divided into 222,293 households, with an annual growth rate of 3.68% (CBS 2009). The forest resources in the state are administratively divided into five forest circles and consist of riparian plantations and dry land forests, both natural and plantations. The riparian forest reserves are distributed along each bank of the Blue Nile and its tributaries Dinder and Elrahad seasonal streams. The riparian forests are dominated by

Acacia nilotica, planted on the flooded part of the flood basins. Other commercial indigenous and exotic tree species are grown *Eucalyptus species*, *Khaya senegalensis*, *Tectona grandis*, *Dalbergia sisso* and *Oxytenanthera abyssinica*. The dry land forests are dominated by *Acacia seyal*, *Acaciasenegal*, *Zizyphusspina-christi,Balanitesaegyptiaca* and *Acacianubica*. The economy of Sennar State is predominantly agricultural. Main crops are *Sorghum bicolor* (Dura), *sesamum indica* (Sesame), *Gossypium spp.* (Cotton), *Helianthus annuus* (Sunflower), *Arachis hypogeal* (Groundnuts) and some horticultural crops.

2.2. Data collection

The field work was carried out during March, May and December, 2010. Primary data was collected through extensive household survey using direct interviews to investigate the household size, and type, source, collection and consumption patterns of household energy in Sennar State.

2.3. Sampling techniques and sample size determination

Household was treated as the sampling unit. Equation (1) according to Israel (2009) was used to estimate sample size

$$\mathbf{n} = \frac{\mathbf{N}}{1 + \mathbf{N}(\mathbf{e})^2} \text{.....(1)}$$

Where:

n is the sample size.

N is the population size

e is the level of precision.

With a precision level e of 5%, a confidence level of 95%, maximum variability (0.5) and a population size (N) of 222,293 households, the sample size (n) of 400 households was determined. Sample sizes of localities were calculated relative to population density as 129, 168, and 103 for Singa, Elsouki and Abuhojar, respectively. Within each locality selection of village respondents was made randomly.

Figure 1: Location map of Sinnar State (shaded)

2.4. Data analysis

Statistical Package for Social Sciences (SPSS) version 17 was used for the statistical analysis. Descriptive statistical methods, comparison of means and analysis of variance were applied to analyze data concerning socioeconomic profile of respondents and quantities collected, consumed and sold of wood fuels.

3. Results and discussions

3.1. Household size

Table 1 displays that majority of households in the study area (56.8%) have a family size of six to nine, followed by households of two to five(24%). Larger families tend to be less common. According to O'Neill and Chen (2002) the sharing of energy services results in lower per capita energy use in larger households. The smaller proportion of large (> 13) household in the study area may contribute to relatively higher per capita energy consumption leading to comparatively more energy consumption.

Table 1: Household size (%)

Locality	**% of household members between**					
	2-5	6-9	10-13	14-17	18-21	22-25
Singa	27.1	51.2	17.8	2.3	1.6	0.0
Elsouki	20.4	65.4	13.6	0.0	0.0	0.6
Abuhojar	24.0	56.8	16.8	1.5	0.8	0.2
Weighted mean	24.0	56.8	16.8	1.5	0.8	0.2

3.2. Household energy

3.2.1. Type of energy for household use

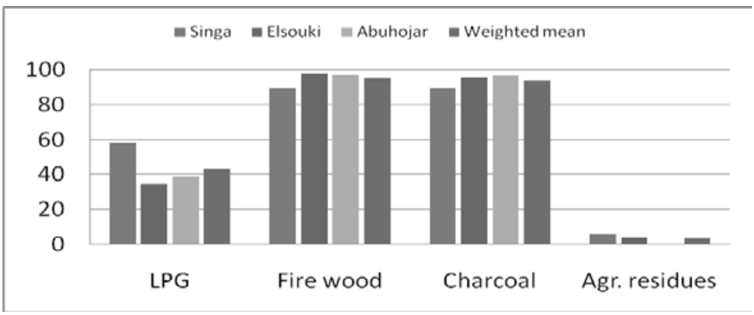

Figure 2: Percentages of energy types used by households

Figure 2 displays the main types of energy used at households where high dependency of households on biomass energy (firewood and charcoal) takes the lead with a mean of above 94% of household energy domestic use Comparable findings were reported by FAO (1999), Gaafar (2011), Eldirdiri et al. (2012) and Adkins et al. (2012).

Sinnar State demonstrates high level of utilization of LPG (58.3%) relative to a national average of 6% (Hood, 2010) which may be attributed to the increase of supply resulted from the recent production of petroleum in Sudan d the establishment of adequate networks of storage and distribution of LPG. However, the overall adoption rate of LPG in the study area is low relative to wood fuels. Hood (2010) reported that notwithstanding government incentives and the expansion of the LPG distribution network, and the clear benefits of LPG use, the penetration of LPG use across households Sudan as a whole is still very low at about 6 percent. The main barriers to the widespread use of LPG in Sudan identified are relative large investment in LPG appliances, price competitiveness of LPG against low prices of woodfuel, lack of infrastructure for LPG distribution, lack of information and socio-cultural issues. In many developing countries, the high costs of modern cooking energy (LPG and electricity) and their cooking stoves are major constraints for household fuel preferences (Ouedraogo, 2005). Agricultural residues are of limited use as a type of energy in the study area.

3.2.2. Means of securing wood fuels

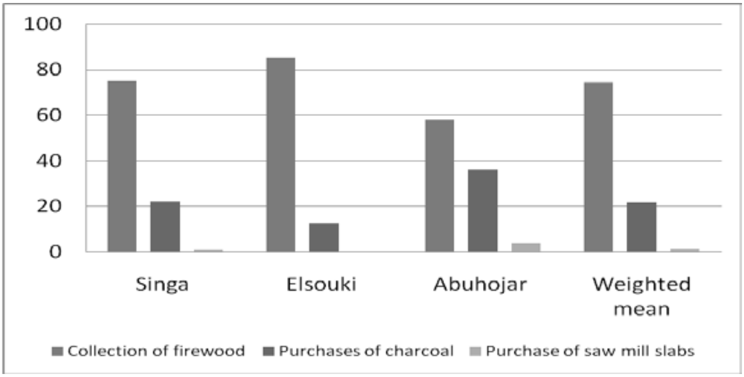

Figure 3: % of means of acquisition of household energy

Collection of firewood remains to be the main method followed by households to meet energy demand. Figure 3 reveals that the majority of respondents (74.4%) depends on direct collection of firewood relative to market purchase of charcoal or sawmills slabs. This finding matches with Adkins et al. (2012) stating that majority of the fuel wood used in households (79%) was acquired by collection, whereas 18% was purchased. Purchase of charcoal is meant to meet special cooking and cultural practices. Adkins et al. (2012) noted that greater fuel wood purchase in drier sites and fuel wood collection data suggest that gathering is more difficult in drier conditions. The nature and limited supply of sawmill slabs and saw dusts allow only small number of households to make use of it.

3.3. Household firewood

3.3.1. Collection and consumption of firewood

Table 2: Quantity of fire wood collected and consumed (bundle/day)

Locality	% of households who collect/ consume firewood (bundles per trip)							
	Collect					Consume		
	1-5	6-10	11-15	16-20	>20	<1	1-3	>3
Singa	54.7	15.1	6.6	3.8	2.8	8.2	77.9	10.6
Elsouki	80.9	3.1	0.7	1.2	2.4	0.6	84.0	13.6
Abuhojar	53.7	0.9	0.0	0.0	2.7	1.8	89.9	3.7
Weighted mean	65.7	5.9	2.1	1.6	7.9	3.3	83.7	9.3

Table 2 indicates that majority of households collect between 1-5 bundles (part of a head load equivalent to approximately 3 Kg each) of firewood per day, while most of them consume1-3 bundles per working day. Assuming average household size and quantities collected of firewood, per capita mean daily consumption rate was 0.86 kg equivalent to 0.36 m^3 per year (0.15 TOE) or 2.5 m^3 (1.15 TOE) per household per annum. It is equal to national mean of 0.36 m^3/yr (0.14 for urban and 0.46 for rural) reported by FNC/FAO (1995) and by Gaafar (2011) for Sudan and mean use rates of 2.5 kg reported by Adkins et al. (2012) for some Sub-Saharan Africa and comparatively less than 0.5 TOE for Africa (Koskimäki, 2012). The higher quantity collected than consumed per day may be an unspoken way of saving for the future or an element of sale of excess is involved to gain more income.

3.3.2. Regularity and time of fire wood collection

Table 3: Frequency and time of fire wood collection

Locality	% of households who collect firewood every(day)				% households with collection time (hour/return trip) of				
	1-7	8-14	15-21	22-30	1-2	2-3	3-4	4-5	5-6
Singa	9.6	15.4	12.2	39.4	30.1	40.8	11.7	4.9	1.0
Elsouki	3.1	20.4	2.5	60.5	71.0	15.4	1.2	0.0	0.0
Abuhojar	0.0	8.3	0.0	47.7	48.1	5.6	0.0	0.0	0.9
Weighted mean	4.0	15.5	6.9	50.9	53.1	19.6	0.8	1.3	0.5

Table 3 shows that firewood collection is almost a daily activity for more than half of the respondents (50.9%).Time spent by household members on collecting firewood varied between one and six hours. However, a return trip mostly takes on average 1 to 3 hours indicating scarcity and associated difficulty. The relatively short mean daily time required for firewood collection in the study area may be attributed to resource availability in the form of large tracks of both riparian and dry land forests on one hand and agricultural waste on the other hand. Adkins et al. (2012) reported comparable results that gathering is the primary mode of acquisition, requiring on average, 6 hours per gatherer each week. Firewood collection has become a fulltime occupation. In distance this responds up to half a day's walk away, or more (FAO, 2001).As fuel wood becomes scarce, which is the case in many parts of the world, the collection time has increased and although men do not perceive it, this has many undesirable consequences, which can be clearly seen in many rural region of Sudan. Women have less time for their other important functions, such as cooking, washing, water collection, and child rearing which may affect the nutrition and health of the entire family (Ömer, 2007).

3.3.3. Distance and site of collection and main collector of firewood

Table 4: Distance and site of collection and main collector of firewood

Locality	% households with distance of collection (km) of			% of householdswhose main collector is		
	<1	1-2	>2	Man	Women	Children
Singa	30.8	50.5	8.4	15.2	59.0	13.4
Elsouki	9.3	63.6	13.6	17.3	54.3	13.0
Abuhojar	5.5	46.8	4.6	18.7	27.1	13.1
Weighted mean	14.3	55.0	9.6	17.1	47.9	13.1

As displayed in table 4, mean distance to site of collection of fire wood for most respondents (55.0%) ranged from 1 to 2, with some walk up to six kilometers. Table 4 also shows that woman is the main family member (47.9%) that undertakes the burden of firewood collection. However, men and children are reported to be involved in the process. This finding agrees with Omer (2007) who argues that women, assisted by children almost always, perform the gathering of fuel wood in rural areas of developing countries, and with Falconer (1990) who indicated that the gender dimension in fuel wood collection is signified as women does most of it. This is not surprising as fuel wood is an important input in food preparation which is women's duty in most of households in most African regions. This is consistent with Cooke et al. (2008) who iterate the involvement of both men and women in fuel wood collection. The main source of free collected fire wood is public forest lands. This is particularly true because of the existence - in an alternating manner along the east and west banks of the Blue Nile - of large tracts of forest plantation reserves, and natural and plantation dry land forests. Approximately 70% of rural area supply of fuel wood comes from indigenous forests (reserved and non-reserved) through unplanned illegal felling (Gaafar, 2011). Private and community forests are present in Sinnar State, however, by the type of forest ownership and use rights they are not accessible to local communities.

3.3.4. Comparison of quantities of firewood collected per trip and consumed

Analysis of variance indicates that there are significant differences (α= 0.05) in the quantities collected of firewood per trip. Further multiple comparisons indicate that the mean difference is significant between Singa and Abuhojar and between Elsouki and Abuhojar localities. Mean quantities collected are bigger in Abuhojar locality. One reason is that Abuhojar by its geographical location is relatively more wet making firewood collection more easily. Fuel wood collection data suggest that gathering is more difficult in drier conditions (Adkins et al., 2012). There are often large variations in biomass consumption between neighboring localities. Several factors can cause that include different types of food cooked, different methods or means of cooking, different practices associated with different ethnic groups, economic classes and religions, and different income groups (Hemstock, 2007). There are no significant variations in quantities consumed of firewood between the three localities.

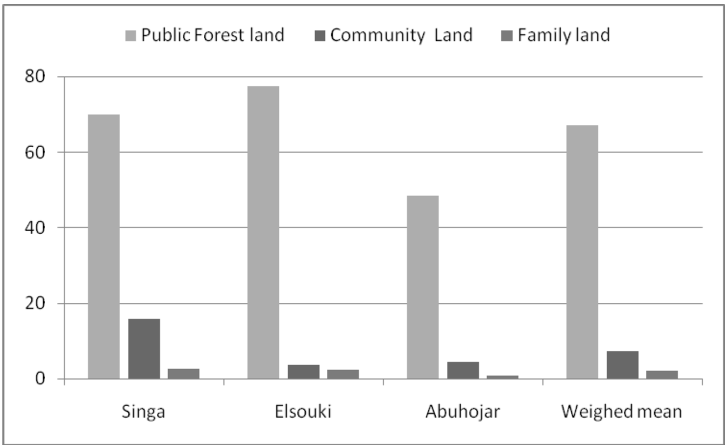

Fig 4: Site of firewood collection

3.3.5. Comparison of distance walked for collection of firewood

Distance walked for collection of wood products is significantly different between Elsouki and Abuhojar localities. It is longer in Elsouki locality. More household members walk longer distances in Elsouki relative to other localities

4. Conclusion

The present study focused on pattern, acquisition and use of energy at household level in Sinnar State, Sudan and the relevant socioeconomic factors. It is concluded that households remain dependent on wood fuel as the main source of energy. Free collection of firewood involves a mean walking distance of around 2 km and that woman is the main collector. Per capita mean daily consumption rate was 0.86 kg (0.36 m^3 per year equivalent to 0.15 TOE per capita per annum) with significant differences between some localities in the quantities collected.

References

Abrahamse, W., Steg, L., Vlek, C. and Rothengatter, T. (2005) A review of intervention studies aimed at household energy conservation. Journal of Environmental Psychology 25, 273–291.

Adkins, E., Oppelstru, K. and Modi, V. (2012) Rural household energy consumption in the millennium villages in Sub-Saharan Africa. Energy for Sustainable Development 16, 249–259.

Bailis, R. (2009) The household energy access challenge. Renewable energy for development 22(2), 2-3.

Bildirici, M.E. (2013) Economic growth and biomass energy. Biomass and bioenergy 50, 19-24.

Blum, H. and Legey, L.F.L. (2012) The challenging economics of energy security: Ensuring energy benefits in support to sustainable development. Energy Economics 34, 1982–89.

Brounen, D., Kok, N. and Quigley, J.M. (2013) Energy literacy, awareness,and conservation behavior of residential households. Energy Economics 38, 42–50.

Cai, J. and Jiang, Z. (2008) Changing of energy consumption patterns from rural households to urban households in China: An example from Shaanxi Province, China. Renewable and Sustainable Energy Reviews 12, 1667–80.

Central Bureau of Statistics (CBS) (2009) Fifth Population & Housing Census 2008 Priority Results. Khartoum, Sudan.

Cooke, P., Kohlin, G., Hyde, W.F. (2008) Fuel wood, forests and community management- evidence from household studies. Environment and Development Economics 13, 103-135.

Couture, S., Garcia, S. and Reynaud, A. (2012) Household energy choices and fuel wood consumption: An econometric approach using French data. Energy Economics 34, 1972–1981.

Ekholm, T., Krey, V., Pachauri, S. and Riahi, K. (2010) Determinants of household energy consumption in India. Energy Policy 38, 5696–5707.

Eldirdiri, F., Adam, Y.O. and Mohammed, H.M. (2012) Development of Liquefied Petroleum Gas (LPG) and household woodfuel consumption: Case study of two rural areas in Gezira State, Sudan. Conference on International Research on Food Security, Natural Resource Management and Rural Development organized by: Georg-August Universität Göttingen and University of Kassel-Witzenhausen.

Falconer, J. (1990) Hungry season's food from the forests. Unasylva 41, 14-19.

FAO (1999) The role of wood energy in Africa. Wood Energy Today for Tomorrow. FAO Corporate Document Repository. FAO, Rome.

FAO (2007) State of the world's forests. FAO, Rome.

FAO (2001) Future production from forest plantations. Report based on the work of C. Brown. Forest Plantation Thematic Papers, Working Paper FP/13. Forest Resources Development Service, Forest Resources Division. FAO, Rome.

Forests National Corporation (FNC) and FAO (1995) Forests products consumption survey in Sudan: summary of findings. Forestry development project, FAO-GCP/SUD/047/NET, Khartoum, Sudan.

Gaafar, A. Forest plantations and woodlots in Sudan. African Forest Forum working paper series 2011; 1(15).

Hemstock, S.L. (2007) The assessment of biomass consumption In: Rosillo-Calle, F., de-Groot, P., Hemstock, S.L., Woods, J., editor. Biomass assessment handbook: bioenergy for a sustainable environment. UK, London.

Hood, A. (2010) The Use of Liquified Petroleum Gas (LPG) in Sudan. United Nations Environment Programme, Khartoum.

Israel Glenn, D. (2009) Determining sample size. Agricultural Education and Communication Department, Florida Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida. Publication no. PEOD6.

Joon, V., Chandra, A. and Bhattacharya, M. (2009) Household energy consumption pattern and socio-cultural dimensions associated with it: A case study of rural Haryana, India. Biomass and bioenergy 33, 1509-12.

Koskimäki P. (2012) Africa could take a leap to energy efficiency: what lessons could Sub-Saharan countries could learn from European countries energy efficiency policy implementation? Energy for sustainable development 16, 189-196.

Liu, G., Lucas, M. and Shen, L. (2008) Rural household energy consumption and its impacts on eco-environment in Tibet: Taking Taktse County as an example. Renewable and Sustainable Energy Reviews 12, 1890–1908.

Omer, A.M. (2002) Energy supply potentials and needs, and the environmental impact of their use in Sudan. The Environmentalist 22, 353–365.

Omer, A.M. (2007) Renewable energy resources for electricity generation in Sudan. Renewable and sustainable energy Review 7, 1481-1497.

Omer, A.M. (2009) Sustainable energy: Challenges of implementing renewable technologies. Journal of Agricultural Biotechnology and Sustainable Development 1, 1-23.

O'Neill, B.C. and Chen, B.S. (2002) Demographic determinants of household energy use in the United States. Population and Development Review. Supplement: Population and Environment. Methods of Analysis 28, 53-88.

Ouedraogo, B. (2006) Household energy preferences for cooking in urban Ouagadougou, Burkina Faso. Energy Policy 34, 3787–95.

Pachauri, S. (2004) On measuring energy poverty in Indian households. World Development 32(12), 2083–2104.

Vaage, K. (2000) Heating technology and energy use: a discrete/continuous choice approach to Norwegian household energy demand. Energy Economics 22, 649–666.

World Bank (1996) Rural energy and development: improving energy supplies for two billion people. Washington D.C.

Value Chains of Non-Timber Forest Products

Role of Gum Arabic Stakeholders at Elobeid Crops Market under Different Policy Measures

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Abstract

The potentiality of gum arabic sector in Sudan is significantly structured by the performance of its marketing system. The existing marketing system in the country consists of three sub-systems: the rural traditional, the urban and the auction markets. The current paper is intended to describe and assess the role of gum arabic (GA) stakeholders at Elobeid Crops Market under a variety of policy measures. Inquiries, in such respect, entail the display of the role of stakeholders with regard to the different policy scenarios. In this context, the paradox of policy interventions in terms of concession measures and its abolition is considered. This expresses itself in different packages including market infrastructures, administrative setups, marketing channels, forces of supply and demand, pricing mechanisms and quality control measures. The paper applied a composite of research methodologies including descriptive statistics and policy analysis matrix. The findings revealed that GA producers, as major stakeholders, do not often exist physically at El Obeid Crops Market. In addition, the gum arabic companies do not show up directly at the auction market. Results also emphasized varying comparative advantages and competiveness pertaining GA trade at the auction market. Additionally, the oligopoly nature of the market is still predominating despite the adopted liberalization measures. Having understood the nature and complexity of GA local marketing

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systems in the region, the current paper suggested some prospects that might empower stakeholders in GA marketing.

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1. Introduction

The majority of the populations in the gum arabic producing areas in Sudan rely heavily on traditional agriculture, livestock and range activities due to their considerable contribution to the household food security (Mahmoud, 2004). GA commodity contributes significantly to the export portfolio of the country. Historically, Sudan commanded over 80% of the world's GA production and trade. Enigmatically, Sudan's share of the GA world market has declined to about 50 percent as being lost to new producing countries in Africa (Couteaudier, 2007). According to records of the Gum Arabic Board (2012), the GA export was around 30,000 tons in 2008, increased (57%) to 47,000 tons in 2009, increased again (17%) to 55,000 tons in 2010, and then decreased (39%) to 39000 tons in 2011.

The GA marketing in Sudan before the inception of the Gum Arabic Company (GAC) apparently exhibited that auction markets were organized by the local government consuls as part of the crops marketing system. A minimum floor price was introduced to the auction system since 1922. The GAC has been established in 1969, and offered exclusive monopoly power on GA trade. Consequently, GAC was the sole exporter of crude GA from Sudan and the world price dominant supplier for about 40 years (1969-2009). The company was mandated to protect GA producers through sustaining a minimum (floor) price. Moreover, it was authorized to supervise and promote the international marketing of GA with the objective of increasing its exports earnings and preserving the GA quality control (Karama, 2002). However, recently in 2009, the GAC power was abolished and the newly-emerging GA processing companies have become very dynamic in GA marketing. From all these experiences, it is obvious that the marketing system of the commodity is directly structured the potential stakeholders involoved at the different GA marketing levels. The system comprises the rural traditional, urban and auction markets (Mahmoud, 2004). The traditional GA marketing patterns, in turn, are aggravated by poor infrastructures, weak administration setups and policy distortions. These factors have severely affected GA marketing processes. Consequently, the producers and local traders in the rural markets receive very low prices or supplies much lower in values compared to their GA harvest. The presence of these rural markets, as criticized by El-Tohami and Bateson (1986), has a damaging effect of divorcing producers' response away from official pricing policies. Estimates of Couteaudier (2007) showed that GA prices paid to producers in rural markets were for many years typically about 10 to 15 percent of the FOB prices. The on-going efforts exerted by some developmental projects like the "Revitalizing the Sudan Gum Arabic Production and Marketing" project financed by the World Bank-administered Multi-Donor Trust Fund- National, FNC and IFAD (2011) are trying to push up these percentages.

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2. Objectives

The overall objective of this paper is to describe and assess the role of gum arabic stakeholders at Elobeid Crops Market under different policy measures. Specifically, this entails to display of the role of stakeholders pertinent to market infrastructures, administrative setups, marketing channels, forces of supply and demand, pricing mechanisms and quality control measures.

3. Materials and Methods

3.1 Selection of El Obeid Crops Market

Elobeid crops market (main central), was selected on the basis of some economic and non-economic arguments. In this context, the market supplies more than 50% of GA commodity in the country in addition to the availability of marketing records since 1950s. This is besides prevalence of large and diversified number of GA stakeholders.

3.2. Data collection

Participatory learning and action (PLA) and other relevant approaches were pursued to assure good coverage of stakeholders' participation. Interviewing questionnaires with GA stakeholders were conducted. Meetings with different stakeholders and related groups (viz. gum arabic production associations, businessmen federations, custom and tax authorities, quality control units ... etc.) were undertaken. Personal observations were documented with the aid of digital devices. Secondary data were extracted from the market reports and previous studies. Time series data for quantities and prices of GA commodity were obtained from different sources.

3.3. Analytical tools

The collected data were analyzed using descriptive statistical measures and Policy Analysis Matrix (PAM). PAM as an empirical framework was used to display the degree of government interventions and market failures effect on comparative advantages and competitiveness on the auction market. This exhibits itself in terms of some PAM coefficients like DRC (domestic resource cost ratio), CIC (coefficient of international competitiveness) and EPC (effective protection coefficient). These coefficients were calculated on the basis of Monke and Pearson (1989) & Pearson and Gotsch (2002).

Whereas:

- The EPC is defined as the ratio of value added in market prices to value added in world prices.
- The DRC, as a measure of efficiency or comparative advantage, is calculated by dividing the costs of marketing (in economic prices) by the value added evolves from the marketing process (in economic prices).
- The CIC is defined as the ratio of the domestic resource costs measured in economic prices and expressed in domestic currency (SDG), to the international value added (IVA) expressed in foreign currency (US$).

4. Results and discussion

4.1. Infrastructures

Elobeid crops market, initiated in 1905, consists of different specialized units; information office, auction hall, market yard, executive authority office, electronic balance (maximum load 70 ton ± 20 kg), 20 conventional balances, and nursery. Other offices are allotted for representatives of alms (*Zakat*), taxes and duties, quality control, merchants, producers´ agents and companies' agents. Basic services of water and electric power are available in addition to security elements. There are no storage facilities in the market. Management manpower in the market is more than 100 people, in addition to other employees (taxes, quality control, FNC and alms). Despite deficiency in some essential assets and poor market information system, Elobeid crop market is comparatively the most appropriate GA auction market in the country.

4.2 Marketing channels

Gum arabic marketing channels refer to the vessels whereby gum arabic commodity is transferred from producers to the central markets as El Obeid and Ennuhoud Crops Market. GA marketing channels differ a little in each market level due to the variability in number and types of stakeholders, distance to the central market, accessibility all over the year and means of transportation.

4.3. Stakeholders

Three types of stakeholders dominate Elobeid crops market. These are the producers' agents, city merchants and companies' agents. This is beside the executive authority related to market daily work. GA producers do not physically exist at the auction market due to some reasons argued by the key informants. These arguments imply that producers do not satisfy auction market requirements, they are scattered over remote areas from the auction market, a considerable portion of them are not aware of auction markets, some of them preferentially sell their GA product at low prices to meet their urgent daily needs and the quantity required by auction markets is relatively beyond their capacity.

With regard to the number of traders during the GAC concession, Figure (1) expresses the number of registered traders in Elobeid auction market for the period (2005- 2009). The trend of their number showed significant (R^2 = 0.677) decline for the prescribed period. This is presumably ascribed to disfavoring gum arabic prices offered at the auction market, lack of credit facilities, high taxes and fees and fluctuation in gum arabic production.

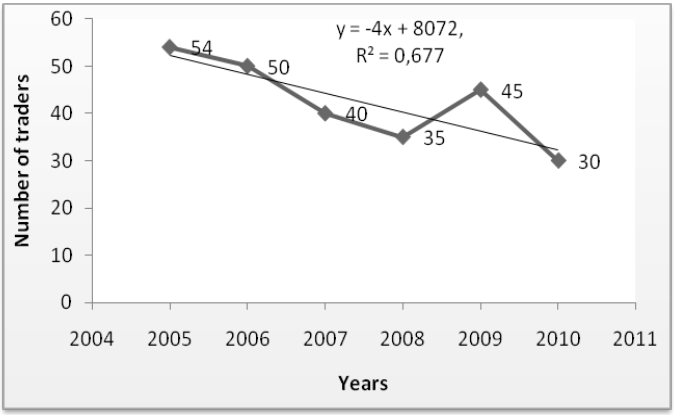

Figure 1: Number of registered traders at Elobeid crops market during 2005-2010
Source: Records of Elobeid Crops Market (2010)

The findings also illustrated that despite their crucial role in the GA auction markets, gum arabic companies do not show directly at the auction market. The reasons behind are primarily the severe taxes and crops alms (*Zakat Elzroa*). Furthermore, there is a general consensus among gum arabic companies that their physical appearance at the auction market will lead to a substantial jump in GA prices. Nonetheless, some companies have active agents at the rural and urban GA markets. It is worth to note that auction competition for GA is presently decreased presumably due to the relatively few dealers which could be described from economic standpoint as sheer oligopoly. This phenomenon implies that dealers in the gum arabic auction market do not exert efforts towards favoring neither small producers nor rural traders as mandated by GAC.

Gum arabic companies don't show up physically in the auction market and concurrently perform their active transactions in rural and urban markets. This could be attributed to inadequacy in price incentives provided by the auction market and high taxes versus preferential profit margins offered in rural and urban markets.

4.4. Market forces and pricing mechanisms

Based on the current price liberalization policies issued by the Presidential Decree in 2009, the GA minimum floor price is no longer valid. This situation, most likely, leads to uncertainty of GA prices, especially in rural and urban markets. Though the interviewees at Elobeid crops market assured the competitiveness of gum auction market, the cross-checked investigations revealed that GA price is solely determined by the buyers (traders, middlemen and companies' agents). The observations gathered by authors also emphasized that the sellers of the commodity at the auction market deliberately keep low profile, in most cases, during the bidding process. In this context, the interviewed stakeholders (80%) alleged that the market is of a competitive nature (Figure 2). However, the analysis refuted this idea in the sense that the market is an oligopoly rather than competitive one. Again, the few numbers of registered gum arabic traders and companies confer strong arguments in favoring the oligopolic nature of the auction market.

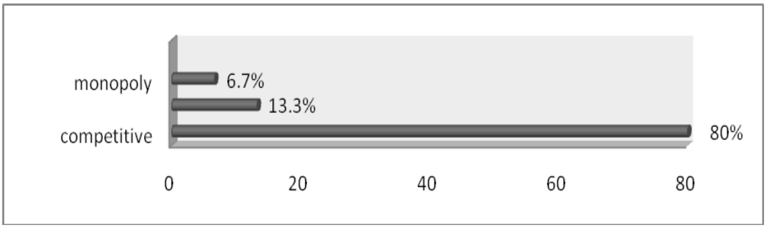

Figure 2: Nature of Elobeid crops market according to the interviewees

4.5. Quantities and prices of Gum Arabic

The quantities of gum arabic received at Elobeid crops market during 1960-2009 showed fluctuations with a trend of a steady decline.

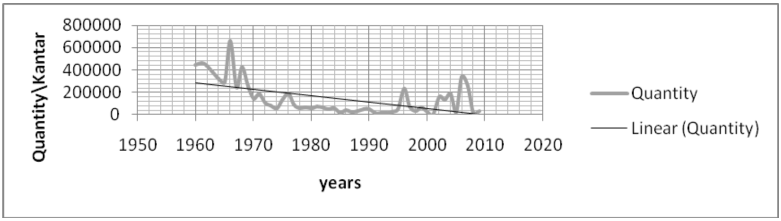

Figure 3: Quantities of GA received at Elobeid crops market (1960- 2009)
Source: Elobeid Crops Market, Information Unit (2011)

One of the most expressive findings is that the combined quantities that reported at the market during the ten years period (1960-1970) were surprisingly much higher than those received during the subsequent 38 years (1971-2009) collectively. The deterioration in gum arabic quantities received at Elobeid crops market during the last 38 years might be attributed to the disincentives created by policy distortions and market imperfections. It is conceivable that total GA supplies to be received at auction markets will be decreasing during this season (2011) and subsequent seasons due to the serious problem of the deviation of the labor force from gum and crops production to conventional gold mining in all states where gold has been discovered, especially North Kordofan State.

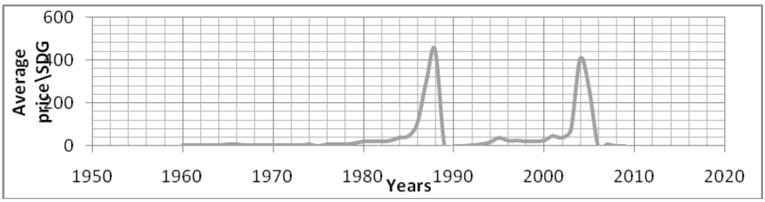

Figure 4: Average prices of GA per *kantar* received at Elobeid crops market
Source: Elobeid Crops Market, Information Unit (2011)

It is worth to note that during season 2005 (Figure 4), the price of GA per *kantar* tremendously escalated due to most likely market speculation. It seems plausible that higher prices in 2005 led to more quantities in the next season 2006 and 2007. However, the negative impacts of these higher prices (not followed by the international prices of gum arabic) have led to accumulation of huge gum arabic quantities in the hands of companies, big names in the business and financial institutions (banks). It was difficult for the authors to report the quantities supplied and purchased at markets like Abugebaiha and Umgafala. This is mainly due to the absence of market records. Despite that, some appreciable quantities were traded and stored in these markets as expressed by interviewees.

4.6. Comparative advantage and competitiveness of gum arabic in Elobeid auction market

The PAM was applied to investigate the effect of price policy interventions on gum arabic commodity in Elobeid auction market. This was done through testing the adequacy of price incentives generated from financial returns per *kantar* of GA for the years 2007, 2008 and 2009.

As presented in Table (1), the following empirical indicators were obtained and explained as follows:

iv. The effective protection coefficient (EPC<1.0, and decreasing from 2007 to 2009) emphasizes the cumbersome burden of direct and indirect taxes imposed on marketing of GA commodity. As a result, the prevailing price policies were considered discouraging the competitiveness of the commodity in the auction markets i.e., the incentives offered through the auction prices were not satisfactory promoting gum arabic stakeholders. The results also justify that the gum arabic auction prices were not determined on the light of the export prices.

v. The domestic resource cost ratio (DRC<1.0, and increasing from 2007 to 2009) for GA auction market indicates a positive (but decreasing as from 2007 to 2009) comparative advantage of the commodity in the auction market.

vi. The coefficient of international competitiveness (CIC) shows that the GA commodity obtained from the auction market is internationally competitive despite the distortion created by government interventions and market inefficiencies.

Though the rural and urban markets of GA (e.g. Umgafala and Abugebaiha markets) were not investigated by PAM analysis due to deficiency of some technical data, the PAM model is expected to exhibit different indicators.

Table 1: PAM indicators for GA commodity in Elobeid crops markets:

Year	EPC	DRC	CIC (SDG)
2009	0.41	0.53	177.39
2008	0.77	0.36	135.00
2007	0.83	0.29	101.55

5. Lessons learnt and Future prospects

Suggested future prospects were deducted from the situation analysis of Elobeid Crops Market. In view of that, the following measures are suggested:

- Encouragement of intellectual (smart) partnerships between GA producers and the private sector on the basis of benefit sharing or powerful sharing to assure the presence of GA producers in all levels of markets.
- Facilitation of microfinance through easy collaterals for GA producers and local traders.
- Changing official perception on GA markets from being markets for levying revenues to markets for providing real services.
- Auction markets should be pushed towards more realistic and competitive transactions in a sense that prices of gum arabic to be determined on the light of market forces (supply and demand).
- Improvement of infrastructures at the gum arabic markets.
- Activation of quality control and standard units at these markets.

- Implementation of gum arabic insurance services in all markets.
- Provision of marketing information systems via establishment of well-equipped trade points and initiation of scientific database for gum arabic trade
- Establishment of powerful networking to connect rural, urban and auction GA markets.

References

Bank of Sudan (2009) Gum Arabic Production (2008 & 2009). Bank of Sudan Annual Report 49 (8), 101-120.

Couteaudier, T.Y. (2007) Export Marketing of Sudanese Gum Arabic, Multi Donor Trust Fund-National,WorldBank,Khartoum.

El Tohami, A. and Bateson, W.M. (1986) Sudanese Gum Arabic Production: Supply Function Estimates and Policy Implications. A Paper Submitted to Planning and Agricultural Economics Administration, Ministry of agriculture and Natural Resources Khartoum (Sudan). Washington D.C.

IIES and IES (1990) Gum Arabic Rehabilitation in the Republic of the Sudan (1990). Stage 1 Report. Volume 2. Main Report and Recommendations for Action. International Institute for Environment and Development, London, England and Institute of Environmental Studies, University of Khartoum, Sudan.

Karama, M. (2002) Gum Arabic Marketing Issues: Marketing Model, Buffer-Stocking, Processing and Finance. Unpublished Paper Presented by the International Workshop on Promotion of Gum Arabic Production, Processing and Marketing (2002). Khartoum, Sudan.

Mahmoud, T.E. (2004) The Adequacy of Price Incentives on Gum Arabic Production and Marketing: A Case Study of North and West Kordofan. PhD Dissertation, Institute of Forest Economics & Management Planning, Dresden University of Technology, TUD Press, Germany.

Monke, E.A. and Pearson, S.R. (1989) The Policy Analysis Matrix for Agricultural Development. Cornell University Press, Ithaca.

Pearson, S. and Gotsch, C. (2002) The Policy Analysis Matrix. Workbook Version, Displayed as a Computer Tutorial.

Phillips, G. O. (2010) Gum Arabic - An Ingredient and Dietary Fibre of Low Calorific Value. Paper Presented in the Conference of New Developments in Acacia Gum Research and Products. Glyndŵr University, Wrexham, UK.

Taha, M. N. (2000) The Socio-Economic Role of Acacia senegal in Sustainable Development of Rural Areas in the Gum Belt of the Sudan. PhD Dissertation, Institute of International Forestry and Forest Products (Tharandt), Technical University of Dresden, Germany.

The Collapse of Frankincense Tree Populations and Frankincense Production is Unaffected by Soil Conditions and Biotic Factors

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Abstract

Regeneration of the frankincense producing tree, *Boswellia papyrifera* (Burseraceae) is scarce, in many studied populations threatening the dry woodlands and the highly valued frankincense production. Here we study the role of regeneration in the dynamics of 12 frankincense tree populations across its habitats in northern Ethiopia using a stage-classified matrix model. Growth, mortality and recruitment were recorded over two years in 12 permanent plots of 1.6 to 2 ha each. With population growth rates (λ) below 1 all 12, populations were declining. In spite of the high seedling recruitment in some of the populations none of the seedlings survived and grew to sapling stage. Overall mortality rate of juveniles and adults (7%) was high. Against our expectation, the elasticity analyses and scenario analysis showed that high recruitment and fast transitions of seedlings to saplings would not lead to a growing population. Instead, only higher large tree survival would imply population increase. The poor recruitment, high adult tree mortality and resultant low population growth rate were unaffected by soil fertility conditions and biotic factors (abundance, basal area, stand volume). Overriding disturbances by fire, grazing or herbivore attacks are probably responsible for the declines in tree abundance and the annual frankincense production capacity over the coming years.

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1. Introduction

Non timber forest products (NTFPs) are materials of biological origin derived from forests, including bark, roots, tubers, corms, leaves, flowers, seeds, fruits, gums, resins, honey, fungi, animal products and only excluding timber (de Beer & McDermott 1989, Ros-Tonen et al. 1995). NTFPs are a major source of livelihood and cash income for rural and urban households in developing countries (FAO 1989, Wollenberg & Ingles 1998, Lemenih et al. 2003).The extraction of NTFPs has been advocated as a land-use practice that integrates forest conservation and economic development of people living in forest areas (see, e.g., Nepstad and Schwartzman, 1992; Allegretti, 1990; Plotkin and Famolare, 1992). NTFP extraction is often thought to be economically viable, ecologically sound, and socially acceptable (Barbier 1987, Arnold & Ruiz-Perez 2001; Ticktin 2004). Unlike logging, the extraction of NTFPs usually shows no or limited signs of changes in forest structure, and is assumed to maintain forest environmental services and biological diversity, and provide opportunities of sound forest management (Peters 1996; Ros-Tonen 2000, Ticktin 2004). More recently, however, it has been shown that exploitation of NTFPs may not always be sustainable (see a review by Hall and Bawa 1993), particular because the exploited trees decline in vigour, and recruitment and abundance may go down (e.g. Perez et al. 2003, Rijkerset al. 2006).

Sustainable extraction of non-timber forest resources can be implemented if periodic inventories show that strong negative impacts of NTFP extraction on tree numbers and NTFP production are negligible (Peters 1996; Hall and Bawa 1993;). Based on such inventories, matrix models can be parameterized (Caswell 2001, maybe a recent paper?) to assess the likely effects of various management strategies on population growth rates (Rist et al. 2010, Pinard & Putz 1992, Waite and Hutchings 1991, Aplet et al. 1994, Smith and Trout 1994, Maschinski et al. 1997,), or of natural or anthropogenic disturbances like fire, grazing, or harvesting (Silva et al. 1991, Nault and Gagnon 1993, O'Connor 1993, Pinard 1993, Bullock et al. 1994, Bastrenta et al. 1995, Olmstead & Alvarez-Buylla 1995, West 1995, Batista et al. 1998). Matrix models have also been used to document spatial and temporal variation in a species' vital rates (e.g., Horvitz and Schemske 1995, Oostermeijer et al. 1996, Kephart and Paladino 1997, Vavrek et al. 1997, Zuidema 2000; Svenning & Macia 2002).Sensitivity or elasticity analyses of these models can identify the life phases and vital rates that are most critical to the population growth (de Kroon et al. 2000, Zuidema et al. 2010), and these life phases should then receive particular attention in management programs (see also Verwer et al. 2008). Life table response experiments even more directly evaluate effects of environmental variation or management regime on the population (Caswell 2001).

Here we present a study on the effect of habitat characteristics (soil conditions), and biotic factors (abundance, basal area, standing volume) on population dynamics of the frankincense-producing tree species Boswellia papyrifera in Ethiopian dry woodlands. B. papyrifera occurs along a wide altitudinal range of 500-1600 m.a.s.l (Friis et al. 2010, Vollesen 1989, Eshete et al. 2011) in areas varying in geology, soil types, topography, climatic conditions (Gebrehiwot 2003, ILRI 2005), and in species composition and vegetation structure (Eshete et al. 2011). We recently showed that the population structure and biomass is mainly driven by variation in soil conditions, and probably less by the encountered climatic variation (Eshete et al. 2011). These populations are under pressure because the traditional frankincense tapping activities in the Horn of Africa have been intensified (Kebede 2010) and lead to reduced tree vigor (Rijkers et al. 2006). Moreover, unregulated grazing and recurrent fires prevent seedling and sapling establishment (Ogbazghi 2001; Gebrehiwot 2003; Abiyu et al. 2010), and land clearing for agricultural expansion degraded B. papyrifera dominated woodlands (Lemenih et al. 2007, Girma et al. inpreparation). These land and tree uses potentially threaten the existence of remaining populations, as confirmed by the missing recruitment class (Ogbazghi et al 2006a, Abiyu et al. 2010) Recently, we reported on the projected decline of populations in Northern Ethiopia, in both tapped and untapped areas (Chapter 4). This chapter examines to what extent habitat characteristics and biotic factors influence the dynamics of 12 tapped and untapped populations.

We use matrix models to predict the present growth rates of the twelve populations, and show how sensitive these population growth rates are to the vital rates in different life phases. Moreover, we explore whether the expected collapse of B. papyrifera populations is similar for populations differing in soil fertility or in frankincense tapping regime. More specifically we addressed the following research questions: (1) How do vital rates (reproduction, stem growth, survival) and population growth rates of B. papyrifera populations vary among populations differing in soil conditions? (2) What are the bottlenecks for achieving persistent B. papyrifera populations? We expect higher growth, survival and reproduction on more productive soils, which have a higher clay contents and deeper soil (Eshete et al. 2011). Since poor regeneration is the common feature of B. papyrifera populations (Abiyu et al. 2010), we expect that lack of recruitment (establishment and survival of seedlings) acts as a major bottleneck for the persistence of the populations. We will discuss our result in the light of the sustainable management of this species and the frankincense production, in areas where increasing numbers of people and organizations get involved in the harvesting, processing and marketing of frankincense (Lemenih et al. 2007, Eshete et al. 2005).

2. Materials and methods

2.1. Study species

Boswellia papyrifera (Del.) Hochst. (Burseraceae) is a deciduous tree that reaches a height of approximately 14 m, has a round crown, contains prominent vertical resin ducts in the bark, and has thick branches tipped with clusters of leaves (Azene Bekele *et al*. 1993, Eshete et al. 2011).The species is distributed in hot and arid areas, often on steep or exposed situations and on rocky slopes or in gullies. In Ethiopia, *B. papyrifera* is encountered in *Combretum-Terminalia* woodlands at altitudes of 600 - 1800 m.a.s.l. (IBC 2007, Friis et al. 2010), average temperature ranging from 20 to 25^{o} C and annual rainfall of 500 - 1000 mm (Eshete et al. 2011, Ogbazghi et al. 2006b). Beyond Ethiopia, this species is also encountered in Nigeria, Cameroon, the Central African Republic, Chad, Eritrea, Sudan, Somalia, and NE Uganda (Vollesen 1989; Azene Bekele et al. 1993). In Ethiopia, *B. papyrifera* provides both wood and non-wood forest products. Wood is important for local people to make household furniture and doors. Leaves are used as fodder for cattle, and honey is exploited (Eshete 2002). The highest economic value is provided by frankincense, a resin obtained by wounding the bark during the dry season. The tapping of frankincense is described elsewhere (Gebrehiwot 2003, Eshete et al. in preparation). Frankincense from *B. papyrifera* has been marketed since ancient times (Groom 1981). Ethiopia was and is still the major producer and exporter of this product. Gebrehiwot (2003) and Lemenih and Teketay (2003b) described the traditional and modern use of the frankincense.

2.2. Study site

The study sites are located in the Metema region in north western Ethiopia (12°33.58' – 12°41.53'N, 36°04.12' – 36°18.84'E). The climate is characterized by > 8 months dry season (Eshete et al. 2011).

According to data from the nearest meteorological station, Shehidi, 25 km away from the study sites, the mean annual rainfall is 965 mm and the mean monthly minimum and maximum temperature are 19.6 and 35.7^{o}C, respectively. The altitude of the studied plots ranged from 595 to 920 m.a.s.l. The sites belong to the lowland dry areas where deciduous tree species dominate the vegetation. IBC (2007) and Friis et al. (2010) classify the vegetation in the study site as Combretum-Terminalia woodlands, dominated by gum and resin producing tree species. Commercial harvesting of frankincense from *B. papyrifera* started long ago in Ethiopia, and since 1996 in the study site (Eshete 2002). We selected 12 populations in 1.6-2.0 ha plots for this study in August 2007. These plots varied in tree abundance (89–302 trees ha^{-1}), basal area (2.5–11.4 m^{2}ha^{-1}) and standing volume (7.3–38 m^{3}ha^{-1}) (Eshete et al. 2011). The plots also varied in soil texture and composition: the clay content ranges from 11 to 58%, organic matter from <1–5%, soil depth from 11. to – 58 cm, and available phosphorus from 1.84 to 50.21 ppm (Eshete et al. 2011). Six of the 12 studied populations were continuously tapped from 1995-2005, but not in 2006. Such a year without tapping is considered a “resting period”. From 2007 onwards the tapping was continued again. The other 6 populations were never exploited for frankincense because they were relatively inaccessible, did not provide water sources to workers, or were considered not sufficiently productive by local tappers (Eshete 2002). Also during our experiment, these populations remained untapped. Half of the tapped plots and of the untapped plots were fenced and protected from fire by creating vegetation free corridors.

2.3. Data collection

In each plot all individual plants of *B. papyrifera* (≥ one year old) were tagged and mapped at the start of the experiment (August 2007). Of all trees less than 1.5 m tall, height and root collar diameter (RCD) were measured, and of trees ≥ 1.5 m their height and stem diameter at breast height (DBH). Newly recruited individuals (at least 1 year old) were tagged and mapped. These new recruits were easy to distinguish from newly emerging seedlings(< 1 year seedlings), because the newly emerging seedlings had two cotyledons. Two plots (Plots 11 and 12) were established in October 2007 and thus new recruits were scored only for 2009. All trees and new recruits were re-measured in August 2008 and August 2009. Mortality was scored every six months starting at the time the plots were established. Trees were considered dead if they were debarked along a dry trunk during the dry season, or had no leaves during the rainy season. These dead trees were monitored also during later censuses to confirm their death. Tree damage (presence of fire scar or sign of insect attack) and possible death causes (due to fire, human cut, wind fall or insect attack) were recorded for dead trees.

For each plot the annual fruit production was determined on 5 trees for each of five diameter classes (diameter class 1 = 10 – 15 cm; 2 = 15 – 20cm; 3 = 20 - 25 cm; 4 = 25 – 30 cm; 5 = ≥ 30 cm). When fruits matured (December – January) the total number of fruit bearing apices per tree were counted. Of these, five apices were selected (one in each cardinal direction and one at the center of the crown) to count the number of fruit produced per apex (Rijkers 2006). From each plot a pooled soil sample (0-20 cm) was taken from three sub-plots (20 x 20 m) and soil physical and chemical variables were determined. Soil physical variables include clay (%), sand (%), silt (%) and soil depth (cm). Soil chemical variables include: organic carbon, nitrogen, available phosphorus, basic cations (Na^+, Ca^{++}, Mg^{++}, K^+), cation exchange capacity, and soil pH. The methods employed to estimate each soil variable are described elsewhere (Eshete et al. 2011, Chapter 2). In that earlier study, we also showed that the stand volume correlated strongly with soil depth and clay %.

2.4. Data analysis

We divided the population into 4 stages and 18 size classes (Chapter 4, Fig. 1). The four stages were referred to as seedlings, saplings, juveniles and adults. The seedling stage that contained only the first size class was characterized by > 1 year age and < 2cm RCD. Plants in this stage class die back every dry season and do not produce a permanent shoot for at least 8 years. Seedlings needed about 10 years after establishment to produce permanent shoot and reach 2 cm RCD (field observation, Birhane, personal communication). The second stage includes the size classes 2, 3 and 4, and refers to saplings with a RCD of > 2 cm and a DBH of < 6 cm (size class 2= 2-4cm RCD; 3 = 4 – 6 cm RCD; 4= 6 – 9 cm RCD). Juveniles are non-reproductive individuals and include only the 5th size class (DBH =6–10 cm). The adult stage includes all individuals that may fruit (DBH ≥ 10 cm). This stage was subdivided into 13 size classes (size class 6 = 10 – 12; 7 = 12 – 14; 8 = 14 – 16; 9=16 – 18; 10= 18 – 20; 11= 20 – 22; 12= 22- 24; 13=24 – 26; 14=26- 28; 15= 28 – 30; 16= 30 – 32; 17= 32 – 34; 18 = >34, inclusive of the lower bound of the interval).

2.5. Stand and population structure

Total plot tree abundance, basal area and standing volume were determined for each population. Abundance was determined as the number of individuals per hectare, basal area was the sum of stem basal area scaled to a hectare (m^2.ha-1), and stand stem volume was estimated assuming a cone stem shape, using the equation,

Volume = basal area×height×1/3..[1]

2.6. Vital rate calculations

For each population the annual vital rates of *B. papyrifera* were calculated based on the 2007-2009 field data. We therefore regressed fruiting probabilities, seed production per fruit, growth rates and survival rates per plot against size.

As mentioned before, the field measurements for fruiting probability and fruit production were collected from 25 trees in the 5 largest size classes (individual in adult stage) per plot. Proportion of fruiting trees per plot was calculated as the number of fruiting trees divided by the total number of study sample trees (i.e. 25). To analyze and determine size specific fruiting probability as well as fruit production per tree, the fruiting probability was regressed against DBH using logistic regression model, and the number of fruits per tree as a linear regression.

Survival rates were calculated for all size classes. For individuals in stage and size class 1 we calculated survival as,

$S = 1 - m$;..[2]

Where m is mortality rate defined as:

$m = \frac{\ln (N_0) - \ln (N_t))}{t}$ ....[3]

where $\ln(N_0)$ is the natural logarithm of individuals at the initial time (2007) and $\ln(N_t)$ is the natural logarithm of individuals at *t* time (2009) (Condit et al. 1995). A two-way ANOVA was employed to test the importance of fencing and tapping on survival rate of seedlings. Logistic regression was used to analyze and determine size specific survival probability of individuals in all other stages and size classes. This analysis was performed for each plot.

Size specific annual growth rates of individual plants were calculated from growth curves obtained from the two years of field measurements. The growth curve was obtained using linear regression models where DBH or RCD and the square of DBH or RCD at year 0 was included as an independent variable. When no relation was observed between growth rates and tree size, average growth rates of the population was calculated.

2.7. Matrix model construction

Two transition matrices that differ in parameterization of matrix elements were constructed for each of the 12 populations: C_m and S_1. C_m matrices were based on the observed vital rates. It shows the population growth of each population under the current situation. S_1 is a transition matrix constructed based on important assumptions for some vital rates. First, we made an important assumption that individuals in the first class would take 10 years to join the second size class, thus growth rate of individuals in this size class would be 2 cm/10 years = 0.2cm per year. Second, as indicated in Chapter 4, the individuals in the 2nd, 3rd, and 4th classes were missing in all plots. But, we need to calculate the transition elements for the missing classes. Thus, we looked for another site (Adiarkay) where individuals of all size classes were present. In this site we monitored the survival and growth of individuals with root collar diameter of ≥ 2 cm to < 6 cm in diameter at breast height for similar number of years. The survival and growth rate as well as the growth and stasis elements of these classes were estimated based on the two year data. The S_1 transition matrices were then used to analyze the dynamics of *B. papyrifera* populations based on the C_m and with transition elements of the missing classes estimated from the observed vital rates at Adiarkay site and assumed growth element of the first class ($G_1 = 0.2$). Each matrix used a stage-classified transition matrix model to analyze the dynamics of *B. papyrifera* populations (cf. Caswell 2001). The transition matrix models took the form:

$\mathbf{n}(t+1) = \mathbf{A} * \mathbf{n}(t)$,.. [4]

where $\mathbf{n}(t)$ is a vector of the stage abundances at time t, and $\mathbf{A}$ is the matrix containing transition probabilities that describe the contribution of each stage to the population at the next time step. The intrinsic population growth rate is calculated as the dominant eigenvalue, $\boldsymbol{\lambda}$, of the matrix $\mathbf{A}$. The projection interval (from t to $t + 1$) was 1 year.

The matrix **A** contains matrix elements (a_{ij}): Pi, Gij, and F_i. Pi describe the probabilities of surviving and staying in same life stage (stasis), Gij describes the probabilities of surviving and growing from stage i to stage j during the time interval from t to t + 1; and; Fi describe the fecundity value of the i stage class. The value of the growth element G_{ij} was calculated as $G_{ij} = g_i * \sigma_i * C_i^{-1}$, where g_i represents mean annual growth rate recorded in size class i; σ_i the survival rate of individuals in i class and C_i^{-1} represents the class width of i class. Pi was calculated as Pi = σ_i - G_i. Fecundity (F_i) was determined as $F_i = \sigma_i * \Pr\{f\}_i * f_i$, where $\Pr\{f\}_i$ is the probability that an individual in size class i is reproductive and f_i the number of offspring produced by a reproductive individual in size class i. The value of f_i was determined as the size-class specific fruit production, multiplied by the number of seedlings produced that emerged per fruit produced during the previous year.

To test if the population growth rate, λ, (from S_1 transition matrix) of each population is different from 1, confidence intervals for λ were calculated using the first-order approximation proposed by Caswell (1989), that depends on the sensitivity and variation of transitions matrix elements.

Elasticity analysis was used to get important information on the extent to which population growth rate depends on survival, growth and reproduction at different stages in the life cycle (de Kroon et al. 1986, Caswell 2001). The formula for elasticity, e, is given by:

$e_{ij} = (a_{ij}/\lambda) \text{ X } (\delta\lambda / \delta a_{ij})$...[5]

where $\delta\lambda / \delta a_{ij}$ is the sensitivity of the population growth rate to a small change in each transition probability. The elasticity analysis was carried for the two kinds of matrices: C_m and S_1.

2.8. Effect of soil conditions and biotic factors on vital rates and population growth of B. papyrifera

To test the importance of soil conditions for vital rates we regressed different vital rates against each soil physical and chemical variables and tested for a significant slope. These tests were performed at two levels. The first test was at plot level where the average vital rates per plot were used for the test. For the second test we used the vital rates of specific size class to avoid the error that would arise due to difference in size class distribution between plots (chapter 4). Similarly, vital rates were regressed against biotic factors (abundance, basal area and standing volume) To test the relationship between size specific vital rates and soil conditions as well as biotic factors, we chose 5 diameter classes (8 – 12) and the analyses was performed for each class separately. Similar test was performed for the population growth rate and elasticity at plot level. Here we choose clay % (the best proxy for soil productivity in the study sites, Eshete et al. 2011) to depict the results of the regression analysis.

Table 1: Vital rates for the 12 studied populations of *B. papyrifera* in the Metema region, North western Ethiopia. Means and standard error of means (SE) are only shown for growth because those values represent the averaged values per tree across the population. The other vital rates are population estimates. All data were obtained for juvenile and adult trees (>6 cm DBH) over a 2 year period (August 2007 - August 2009). Growth and survival rates are calculated on an annual basis and the proportion of fruiting trees and the annual recruitment are averages of the two years of study.

Plot	Tapping	Annual diameter growth rate (cm)		Annual survival rate	Proportion of fruiting trees (%)	Annual recruitment (no/ha)
		Mean	SE			
1	Untapped	0.26	0.03	0.96	38	65.3
2	Untapped	0.34	0.05	0.90	38	4.4
6	Untapped	0.24	0.02	0.95	45	7.0
7	Untapped	0.23	0.03	0.86	39	29.3

8	Untapped	0.25	0.02	0.93	26	24.0
9	Untapped	0.29	0.04	0.90	42	6.9
3	Tapped	0.39	0.02	0.95	79	4.3
4	Tapped	0.41	0.02	0.92	46	7.3
5	Tapped	0.43	0.03	0.92	70	95.8
10	Tapped	0.27	0.02	0.93	60	3.8
11	Tapped	0.13	0.03	0.95	72	133.1
12	Tapped	0.25	0.02	0.95	40	1.5

3. Results

3.1. Fruiting and recruitment pattern

The percentage of fruiting trees ranged from 26 to 79% among the 12 populations For 6 of the 12 plots, fruiting probability increased with stem diameter and for all plots the number of fruits per tree increased with stem diameter. Tapped trees had a higher probability of fruit production than untapped trees (Fig 1). Approximately, 1/3 of all trees produced fruits in both years, ~1/3 in one of the two years and ~1/3 produced no fruit in both years. Trees of plot 5 produced much higher amounts of fruits than trees of other plots.

Seedlings recruited every year in all plots. The number of recruits per ha, however, varied from 1.5 (plot 11) to 133 ha^{-1} (plot 12) (Table 1). The recruiting plants originate from seeds in most plots. They, however, originated from root suckers in plots 2 and 6, even though trees were flowering and fruiting proliferically in these plots.

2.3. Survival

Survival rate of seedlings in fenced plots ranged between 0.81 and 0.98, and in open plots between 0.54 and 0.93. The overall average seedling survival rate was 0.85 (± 0.38 SE) across plots and was not significantly affected by fencing or tapping (t= 0.961, p > 0.05).

Survival rate of saplings at Adiarkay site was 0.87. Initial root collar diameter showed a significant effect on the survival probability of saplings at Adiarkay site ($p < 0.05$, $R^2 = 0.24$). At population level survival rate of juveniles and adult individuals ranged from 0.86 to 0.96. And the overall mean annual survival rate of juvenile and adult individuals was 0.93 (± 0.01 SE) (Table 1, Fig. 1). Survival probability of juveniles and adult individuals showed positive (plot 7 and 9), negative (plot 5 and 8) or no relation (2, 4, 10 and 11) with initial diameter (Table 2, Fig. 1). Plot 1, 3, 6 and 12 showed an increase in survival probability for the first small diameter size then a decrease in survival probability with diameter size since the square of DBH was negative in the regression model. Insect attack, windfalls and human cut were the major sources of mortality accounting for 77%, 21% and 2%, respectively, of all deaths among juveniles and adults trees of > 6 cm DBH.

3.3. Growth

Seedlings died back during the dry periods of the two study years. The growth of root collar diameter as well as the height of re-shooting seedlings were not related to the initial root collar diameter or height (n= , $P > 0.05$). The linear regression test showed that growth of saplings at Adiarkay site was independent of initial root collar diameter ($p > 0.05$). Average growth rate of saplings was 0.5 cm/year. Average growth rate of juveniles and adults together ranged from 0.13 (plot 11) to 0.43 cm/year (plot 5). In 9 out of the 12 plots growth was affected by DBH, in most cases growth rates increased linearly with DBH (Fig. 1., Table 2)**.**

Table 2: Stem growth, survival and fruiting probability of *B. papyrifera* trees as a function of tree size for 12 populations at Metema, northern Ethiopia. Only trees > 6 cm diameter at breast height (DBH) were considered. Multiple linear regression results are shown.

Plot	Growth			Survival			Fruiting probability (2007)			Fruiting probability (2008)		
	Const.	DBH	DBH^2	Const.	DBH	DBH^2	Const.	DBH	DBH^2	Const.	DBH	DBH^2
1	-0.212	0.053	-0.001	-0.25	0.26	-0.006	-2.143	ns	0.004	-0.944	ns	ns
2	0.31	0.02	ns	1.493	ns	ns	-0.095	ns	Ns	-0.916	ns	ns
3	0.33	0.03	ns	-1.196	0.334	-0.007	0.887	ns	Ns	1.946	ns	ns
4	-0.14	0.06	-0.001	1.7	ns	ns	-0.167	ns	Ns	-0.167	ns	ns
5	0.28	0.02	ns	2.24	ns	-0.001	-1.966	ns	0.007	-1.232	ns	0.004
6	0.33	0.01	ns	-2.417	0.555	-.015	-0.105	ns	Ns	-0.318	ns	ns
7	0.23	ns	ns	-1.107	0.123	ns	1.224	ns	Ns	-	-	-
8	0.304	0.011	ns	2.5	ns	-0.002	-3.634	0.168	Ns	-	-	-
9	0.29	ns	ns	0.191	0.048	ns	-0.241	ns	Ns	-2.99	0.11	ns
10	0.152	0.025	ns	1.892	ns	ns	0	ns	Ns	0.847	ns	ns
11	0.13	ns	ns	2.226	ns	ns	-1.998	0.15	Ns	-2.287	0.141	ns
12	0.201	0.014	ns	-0.712	0.269	-0.006	-0.405	ns	Ns	-5.473	0.211	ns

Note: ns = not significant

3.4. Matrix model output

The population growth rate λ of the 12 *B. papyrifera* populations ranged between 0.86 to 0.98 per year (average λ = 0.92 ± 0.03 SD) in the period 2007 – 2009, indicating declining populations in all studied plots. The elasticity analysis showed that the most important matrix element is stasis, in particular the survival rate of the largest size class. This suggests that mainly the survival of the largest individuals is critical for the persistence of populations in the present conditions.

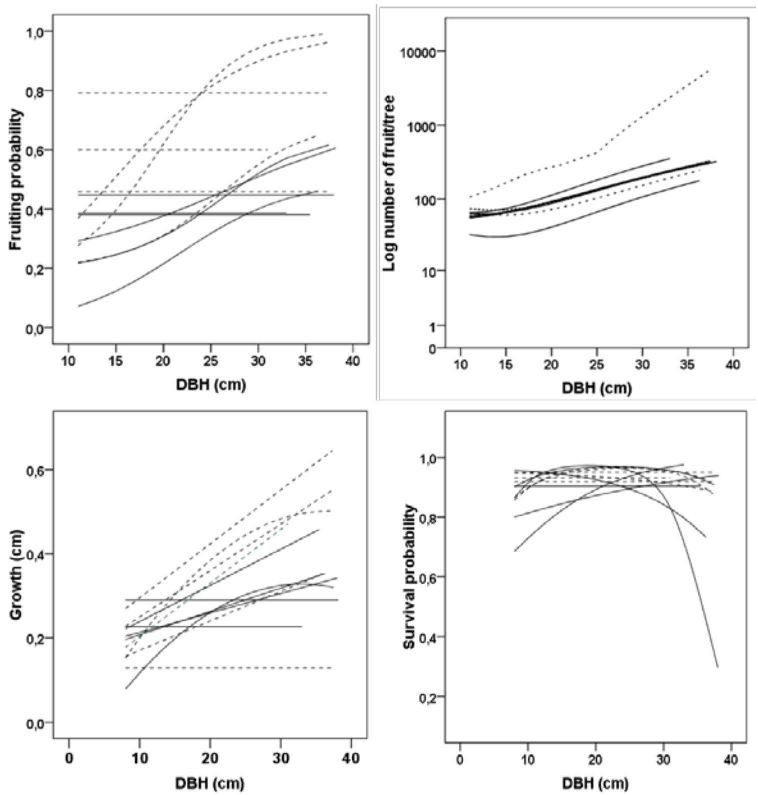

Figure 1: The relationship between vital rates and stem diameter in each of the 12 studied population of B. papyrifera at Metema, NW Ethiopia. Lines are regression lines according to stepwise multiple regression models for growth and fruit production and logistic regression for survival rate and fruiting production. Full lines (___) show for untapped plots and dashed lines (---) show tapped plots.

The adjusted matrix models (including regeneration and vital rates of saplings or missing classes in the study sites) showed population growth rates ranging from 0.90 to 0.98 (Fig. 2). Still all λ, except that of plot 11, were significantly lower than1 and thus indicated decreasing populations. Elasticity analysis for these adjusted matrix models in all plots showed that by far the largest proportion of total elasticity is contained in stasis elements (>92.9%), while growth (<6.6%) and fecundity (0.5%) elements had a very low contribution to λ (Fig. 3B). The elasticity analysis also showed that the survival rate of the adult stage was the most important vital rate in determining λ (Fig. 3A). The population growth rates were little affected by changes in the seedling vital rates in all plots.

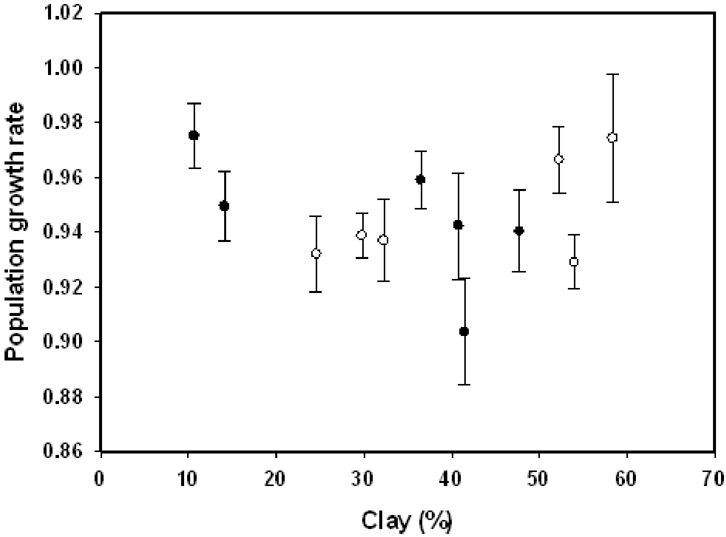

Figure 2: Population growth rate of the 12 *B. papyrifera* populations (calculated from Scenario 1 = with regeneration) in relation with soil clay content. Open circles are tapped plots, closed circles were not tapped. Error bars are standard error of the mean.

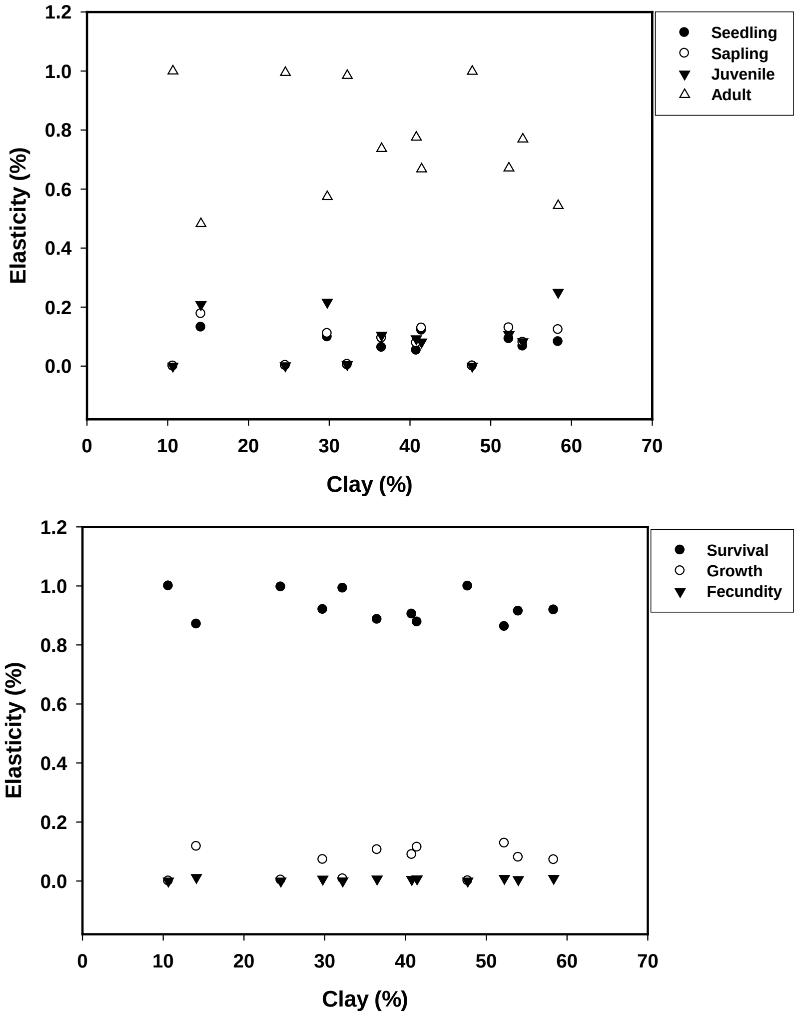

Figure 3: The proportion of total elasticity contained in different lifehases (A) and matrix elements (B). to the population growth rate in relation with soil clay content

3.5. Effect of soil conditions and biotic factors on population characteristics

We predicted higher growth rates, survival rates, and fruiting probability in populations growing on soil conditions with higher clay content, deeper soil depth and better soil fertility. We had also expected higher population growth rates for populations growing in better soil conditions. Contrary to our expectations, however, none of the vital rates (growth rate, survival and fruiting probability) were significantly related to soil conditions (clay content, soil depth and soil chemicals (Fig. 4) nor to biotic factors (abundance, basal area, and stand volume, data not shown). Similarly, population growth rates from the first model and elasticity values obtained from the second modelwere not also related to both soil conditions and biotic factors (data not shown).

4. Discussion

This study evaluates if soil conditions and biotic factors affect demography (vital rates) of *B. papyrifera.* Based on earlier work (Eshete et al. 2011) where we showed that stand volume of *B. papyrifera* populations and of the whole woody plant community increased with soil fertility, we hypothesized that vital rates of *B. papyrifera* populations respond to soil fertility factors. We expected higher growth rates, survival and reproduction effort in response to higher soil fertility. Contrary to our expectations none of the vital rates were related to soil conditions nor to the biotic factors evaluated and biotic factors (abundance, basal area and standing volume).

Irrespective of soil conditions and biotic factors, all populations were characterized by lack of sapling regeneration and high adult tree mortality rates, and resulting in non-sustainable populations. We re-hypothesize that these factors are overruled by relatively recent and strong impacts of disturbance. In chapter 4, we showed that frankincense tapping regime is an unlikely candidate for explaining the decline in the growth rates of these populations, and fire and grazing are more likely candidates.

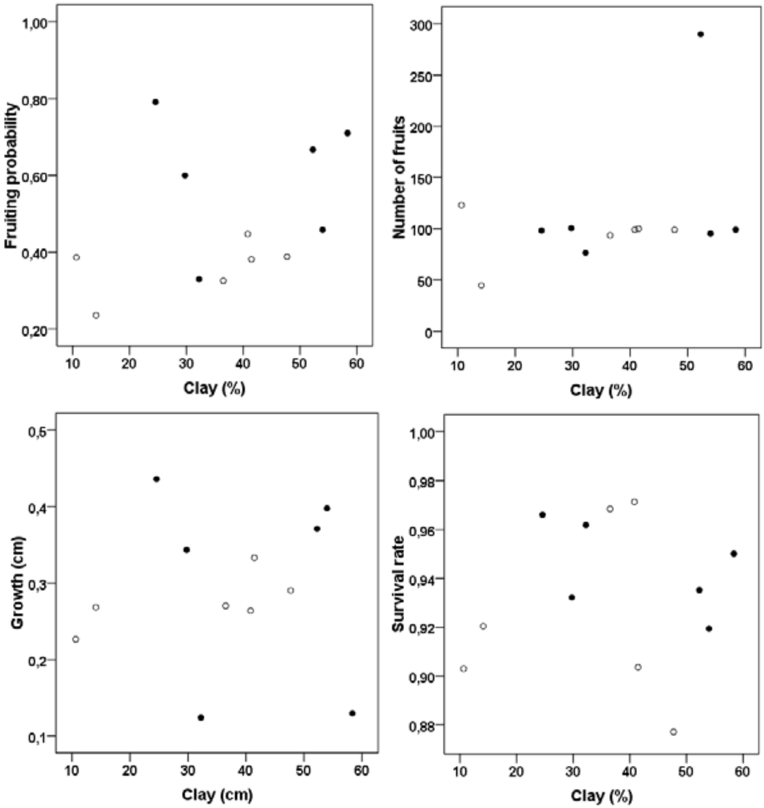

Figure 4: The relationship between vital rates and soil productivity, where clay content was taken as a proxy for soil productivity (Eshete et al. 2011). Tapped populations are indicated by full circles and untapped populations by open circles. We did not find any significant correlation between vital rate (or growth rate) and clay content.

4.1. Vital rates of B. papyrifera across its habitat

Phenology

Soil conditions (water and nutrients availability) in tropical dry forests are essential resources that largely control phenological patterns (Bullock and Solis-Magallanes, 1990) and seed production (Ray and Brown 1994). The study populations varied strongly in proportion of fruiting trees (26 – 79%), but this proportion was not related with soil conditions, in contrast to other findings. Valdez-Hernández et al. (2009) found differences in phenology within species between sites, with higher leaf, flower and fruit production at a site with better soil water conditions. Seghieri et al. (2009) showed fruiting probabilities to decrease with soil moisture in a dry Sahelian site and to increase in a wetter Sudanian site. That we did not find such relationships for *B.papyrifera* trees suggests that fruiting probability might be governed by other factors not considered here, like availability of pollinators and seed dispersers (Seghieri et al. 2009).

Mortality rate

Germination and regeneration of *B. papyrifera* seedlings at Metema occur from June to August during which seedlings have favorable soil water conditions. In the dry season (September to May) the established seedlings die back, probably to avoid desiccation (Fenshaw & Holman 1999; Rice et al. 2004).The mortality rate of established seedlings in the present study populations is low compared to the report made by Gebrehiwot (2003) and Ogbazghi (2001) who reported 86% and 67% of mortality rate of seedlings in Tigray, Ethiopia and Eritrea, respectively. Low mortality rates have sometimes been considered as an adaptive response to considerable climatic stress and disturbance (fire and herbivory) in order to enhance long-term persistence (Sukumar et al., 2005).

Fire and grazing are the commonly reported source of seedlings mortality in dry forests (Zida et al. 2007, 2009, Hoffmann & Solbrig 2003, Menaut et al. 1995), but we did not find differences in mortality rates across management regimes. Fencing had no effect on mortality in our populations, in contrast with findings of Ogbazghi (2001) and Gebrehiwot (2003). Fire also will not be the driver as it occurs during the dry season during which seedlings shed the aboveground and recurrent fire thus will not burn the seedlings. This die-back of seedlings is one of the strategies that dry forest tree species develop to avoid deleterious effect of drought and fire on their regeneration (Fenshaw & Holman 1999; Rice et al. 2004). Once seedlings grow to sapling stage and produce a permanent shoot fire and grazing could have negative effects. This confirms the lack of saplings in all studied populations and elsewhere (see Abiyu et al. 2010) At the Adiarkay site, sapling are present possibly because grazing and fire pressures are much lower (A. Eshete personal observation).

Mortality rates of juveniles and adult individuals in our populations (mean 7%, range 4-14%) are high compared to other dry forests. Annual mortality rates vary from 2.3% in a dry forest in Ghana (Swaine et al., 1990); via 2.9% in a mixed deciduous forest in Thailand (Marod et al., 1999) to 6.9% in dry forests in southern India (Suresh et al. 2010). Fire, grazing, drought, windfall, pest attack and senescence of old stems are considered to be the major causes of tree mortality in tropical dry forests (Sukumar et al., 2005). Some of these factors are related to soil moisture or soil water holding capacity (Condit et al., 1995). The mortality rates in our populations were high across both juveniles and adult stages and survival probability was independent of tree size in most populations. Insect attack followed by windfall were the main sources of juvenile and adult mortality. This result is similar to reports of Negussie (2008). He found that 65% and 85% of tapped *B. papyrifera* trees in Tigray were attacked by the long horn beetle named as *Idactus spinipennis* Gahan. In the present study, particularly insect attack was unexpectedly very common both in tapped and untapped populations and as a result mortality rates did not differ (chapter 4). The overall high mortality rates supported earlier speculations on alarming decline of *B. papyrifera* populations due to human disturbance (e.g, grazing, human cut, tapping, fire, insect attack) (Abiyu et al. 2010, Rijkers et al. 2006, Gebrehiwot 2003, Eshete 2002, 2005, and Tadesse et al. 2002)

Stem growth rates of a dry forest species vary among habitats depending on environmental factors (soil conditions). Water availability and soil conditions that exhibit spatial and temporal variability are the main drivers of tree growth (Ceccon et al. 2006, Mooney et al. 1995, Nath et al. 2006). Dry forest species in soil types that store water well (e.g. high clay% and deeper soil depth) may acquire great stature and biomass (Murphy and Lugo 1990; 1995). Soil fertility can also affect tree growth rate (Lu, et al. 2002; Malhi et al.2004) with better growth on more nutrient-rich soils (Russo et al. 2005, Toledo et al. 2011).

The average growth rate of *B. papyrifera* juveniles and adult individuals (range: 0.13 – 0.43 cm per year, Table 1) was within the reported range of growth rates of tree species in dry forest of Bolivia (Villegas et al. 2009). In Chapter 1 we showed that maximum diameter, maximum height, basal area and standing volume were related to soil conditions associated with water holding capacity (clay content as well as soil depth) (Eshete et al. 2011). Notwithstanding, tree growth rates were not related to soil conditions in the *B. papyrifera* populations examined, suggesting that stand or soil conditions do not govern tree growth rates, as was shown earlier for Amazonian forest (Viera et al 2004). This findings, however, contradicts the reports of Radda and Luukkanen (2006) who found a higher annual growth rate for *Acacia senegal* in soils with higher soil clay content. The absence of such relationship might indicate the presence of other overruling factors responsible for the observed variation in growth rates of *B. papyrifera* trees across its habitats.

4.2. Population dynamics of B. papyrifera

The population growth rate of *B. papyrifera* populations under the current situation varied spatially (range 0.86 to 0.98) but not directly related to soil conditions and biotic factors. Population growth rate lower than 1 indicates population decline if vital rates remain unchanged. Similar population growth rates have been documented for other slow-growing, long lived tree species (Kwit et al. 2004, Silvertown et al. 1993). The low λ-values were the result of high mortality rate of juveniles and adults in all studied populations: the elasticity analysis showed that survival of adult individuals made the largest contribution to λ in all studied populations (Fig. 4). In contrast to our predictions *B. papyrifera* populations decline even under simulated successful establishment of seedlings. During the 2 years of study the decline of *B. papyrifera* populations in Ethiopia thus is not due to lack of recruitment (establishment and survival of seedlings), although the absence of sapling individuals suggest that the growth of established seedlings to sapling stage (< 6 cm DBH) was severely constrained in the recent past. This may be related to the start of inhabitation of the study area in the 1960s as a result of large scale re-settlement (Eshete 2002) Since then people living in and around these forest use fire for various purposes, like clearing for farming, regrowth of new grasses, to walk freely within the forest, and to keep away dangerous wildlife (Eshete 2002). The forests also became the main grazing area for the large herds of cattle of both local inhabitants and nearby highlanders (Eshete et al. 2005, Lemenih et al. 2007). In addition, tapping for frankincense has increased with negative reproductive effects (Rijkers et al. 2006, but see Chapter 4)

Given the results emphasized above, the question arises as to whether *B. papyrifera* populations may persist for long periods of time across its habitats. Our analysis does not allow a straight forward answer to this question given the limitations of our data set (only one area and two years were considered). However, our result showed that all populations experience a demographic decline through time associated with high mortalities of juveniles and adult individuals. Thus, the long term success of the species depend upon the reduction of the high mortality of large individuals and perturbations to seedling establishment, survival and growth would be less effective than those that target juveniles and adult survival (stasis). These results have important implications in terms of forest management: the heavy disturbance observed in the study sites (recurrent fire, heavy and unregulated grazing, improper tapping, Abiyu et al. 2010) that reduced the survival rate of large individuals could further lead to a decline in the abundance of the species. This information is needed for proper predictions regarding population dynamics under different scenarios of human impact, and the results of that for resin production and ecosystem status. As the first long-term study of tree population dynamics at Metema, our results have important implications also for the conservation prospects of this tree species. Furthermore, the nature of disturbance at Metema (e.g. cattle grazing, recurrent fire, improper tapping for frankincense production) is typical of many *B. papyrifera* populations and our results may therefore help inform management decisions in other disturbed *B. papyrifera* populations as well.

References

- to be obtained from the author

The Role of NTFPs in Poverty Alleviation and Sustainable Resource Management in South Kordofan State, Sudan

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Abstract

Livelihood in rural areas in South Kordofan is characterized by low standards of living and high rates of unemployment. Poverty is the main feature of peasant who depends mainly on subsistent farming. The available natural resource, for people especially women, is the utilization of NTFPs. Due to lack of managerial skills of NTFPs and lack of producers and/or collectors organizations, these products are still underutilized. Therefore, proper utilization of non timber forest products (NTFPs) could lead to sustainable forest resources. The aim of this study was to highlight the role NTFPs in poverty alleviation and sustainable resource management in Abukarshola Rural Council, South Kordofan. The potential of the natural forests to produce NTFPs was assessed by means of forest inventory which focused on determination of distribution and density of tree species that supply NTFPs by counting their number and assessment of the status of the natural regeneration. Beside forest inventory, social survey was carried out by using structured questionnaire for 30 farm households, on random sample basis, in two villages in Abu Karshola Rural Council, South Kordofan, Sudan. Focus group discussions were used to cross check the collected data. SPSS software package was used for data analysis. Issues pertaining to the role of NTFPs were assessed. These include access to the resource, annual quantity collected and

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contribution to household income in addition to NTFPs development constraints. The results of forest inventory revealed that the density of trees is much less than the expected because the area is classified as being rich in tree species that produce NTFPs. There is no regulations governing which product should be taken at which time and in which amount; and all inhabitants have free access to all types of NTFPs from natural unreserved forests. The results also indicated that NTFPs contribute to socioeconomic conditions of people and constitute as a main source of income for 20% of the respondents. The results also revealed that extraction of NTFPs is an activity mainly practiced by women, both for household products and income. The 100% female respondents interviewed are engaged in the extraction and processing of NTFPs. To enhance the role of NTFPs, the study recommended that promotion of smart partnership between local communities and private sectors depending on dialogue, transparency and respect is needed.

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1. Introduction

Sudan Forests Sector provides significant opportunities for employment and income generation in almost all rural areas of Northern Sudan. Over the years, forests contributions have been taken into account in official economic reviews (Geller *et al*. 2006); nevertheless, the contribution of forest products to poverty alleviation has not been determined yet. Among these products are non-timber forest products, NTFPs (El Tahir *et al*. 2010) which have an importance that arises from the fact that they are often the only reliable source of food for rural families when crops fail or during the lean periods between harvests (FAO/SIDA 1987). Gumma (2011) investigated the contribution of some NTFPs to rural development-poverty alleviation- in Rashad of Nuba Mountains in South Kordofan, Sudan. NTFPs are important for traditional medicines as they are frequently used by low-income groups in rural areas (Mander *et al*. 1996). In Sudan, there is a general trend to conduct comprehensive studies about NTFPs, their resource potential, utilization and future prospective. Low rainfall woodland savannah, including the south Kordofan of the Sudan, is characterized by open forest areas saved by open woodland. Natural forests are utilized by clear cutting for agriculture, production of fuel-wood and charcoal and building materials for both local needs and commercial purposes. Local people utilize these forests by collection of NTFPs, which are of significant social and economic importance to the families involved. Women are usually dependent more than men do on NTFPs for household use and income. NTFPs are important to women, addressing their needs for food security and nutrition (FAO 1995). Generally, it is realized that south Kordofan confronts over-exploitation or misuse of natural forest resources which let to their degradation. The natural forests in the area are composed of a wide range of tree species produce NTFPs. The sustainability of these products is not guaranteed as the existing potential natural forests that supply these products is not determined, the extraction system is not analyzed and forests are extensively utilized for wood production. Despite the great importance of NTFPs, it has not been given the interest of research and governments. Nevertheless, there is general lack of quantified information on the available forest resources, and the NTFPs in particular, in Sudan. The current study intends to enrich the existing scientific knowledge about NTFPs and their management systems in the area. The objective of this paper is to assess the role of NTFPs in poverty alleviation in Abu Karshola area, south Kordofan, Sudan. The study also aims to provide quantitative data about potentiality of natural forests, to produce NTFPs, namely the density of forest stands that supply local people with the important NTFPs. To fulfill the stated objectives, two assumptions were formulated. First, natural forests in the study area have got a high potential in certain NTFPs however, the current utilization system is not compatible with this potential. Second, NTFPs are of significant importance to socio-economic conditions of people in the area but the sustainability of these products is not guaranteed, as the use of such products does not take into account the resource available and potentiality of various tree species.

2. Methods of data collection

2.1. The study area

The present study was conducted at Abukarshola Rural Council, South Kordofan State the low rainfall woodland savannah of the Sudan. According to Land Use Survey of the Sudan, the landscape of South Kordofan consists of four main regions; these are the Nuba Mountains, the eastern plains bordering White Nile to which the present study area belongs to, the southern plains bordering the Bahr El Arab, and the western sandy plains. The soils belongs to four orders: vertisols (cracking clays), alfisols (textural alluvial horizon), inceptisols (a cambic horizon which shows weak profile development) and entisols (soils lacking profile development but capable of supporting vegetation). Abukarshola Rural Council is a depression surrounded by the Nuba Mountains and located in the east-northern part of the state. In its northern drier boundary, the trees are thorny and small. Acacias dominate the vegetation cover; there are also thorn bushes and shrubs including thickets of *Ziziphus spina-christi*. In the wetter parts towards the southern boundary, broad-leaved deciduous tree species dominate e.g. *Balanites aegypiaca*. Main tribes are the *Bagara*, *Nuba* and *Hawazma* practicing agriculture and livestock as sources of income. Sesame, bean and sorghum represent the most important agricultural crops. Small holder traditional farming dominates most of the population with average farm size 0.6-2.1 hectares per household. Horticultural crop production as a type of land use is also found in small scale, limited to few people who have private lands along seasonal water courses. Forests in Abukarshola are either natural unreserved forests, with unknown extent and area where illegal utilization has seriously took place, or reserved forests with specified areas and some of them have management plans. Forest activities, in both reserved and unreserved forests include collection of royalties from those who collect commercial quantities of wood and NTFPs.

2.2. Data Collection

Before starting the data collection, a comprehensive idea and basic information about the area is necessary. Information pertaining to different types of land use, natural forests situation, distribution of villages in the area, and the general social situation are obtained by a reconnaissance survey. Results of the reconnaissance survey, though were not incorporated the final results of this study, gave an idea about forest accessibility and settlements in and/or around the forests. Methods applied for collection of the primary data necessary for the study include forest inventory work, individual interviews and focus group discussions.

2.2.1. Forest inventory

The potential of the natural forests in NTFPs was assessed by means of forest inventory which focused on determination of distribution and density of tree species that supply NTFPs by counting their number and assessment of the status of the natural regeneration, if any. During the reconnaissance survey, an area of approximately 8000 hectares was covered. A main survey line of 40 km long was determined and a systematic sampling was applied. Sampling points were distributed throughout the survey line in a distance of 5 km between each sampling point and the other. In both sides of each sampling point in the main survey line, two circular sample plots in the same direction were allocated 100 m far from the main survey line. Each sample plot has a radius of 20 m; presenting an area of

0.1256 hectare. A total of 30 sample plots were worked out. For each of the selected NTFPs producing tree species in each sample number of trees per plot, number of natural regeneration and degree of destruction such as grazing and tree cutting, were recorded.

2.2.2. Social survey

Based on information received from Abukarshola Rural Council, the rural villages are found to be homogenous in nature. People are more or less homogenous in their economic activities, farming systems, tribal constitution and social structure such as household composition, family size, male migration and women involvement in gathering forest products. Based upon this homogeneity, only two villages were selected for the social study. 30 samples of households, out of 250, were randomly selected and interviewed. Data about contribution of NTFPs to social economic situation of the people in Abukarshola were collected using a pre-designed questionnaire. The social data covered information pertaining to social characteristics of respondents (age, education, etc.), land ownership and sources of income. Availability of NTFPs, their importance, annual quantities collected and constraints of development were also covered.

2.2.3. Focus group and informal individual discussions

To cross check the data obtained by individual interviews, two focus group discussions were made with local people. The first focus group discussion with village leaders was attended by three women and five men representing salvation committee, which is the local authority in the village. The second one was conducted with women group comprised of six women. In each focus group discussion, the subjects tackled were NTFPs, their importance and contribution to household income, the existing potential of NTFPs and past existence and history of utilization of NTFPs in the area. Official interviews were made with officers in Abukarshola Rural Council covering the same topics discussed in the group discussions. Informal discussions with local people in three village markets and with women groups in their mid-day chatting group were also conducted.

2.2.4. Selection of NTFPs under study

NTFPs under study were selected according to their importance to the people in the area. Information reflecting this importance was collected from informal discussion with people in three market days, discussion with forest officers in Abu Karshola and discussion with the rural council officers and village leaders. Based upon the information collected from all these sources, five NTFPs derived from four tree species were selected. These include *Laloub* fruit from *Balanites aegyptiaca*, *Aradeib* fruit from *Tamarindus indica*, *Saaf* “leaves” from *Hyphaene thebaica*, in addition to *Daleib* fruit and *Halook* “seedlings” from *Borassus aethiopium*.

2.2.5. Data and analysis

Data obtained from forest inventory were analyzed using Excel. Stand density was calculated in terms of number of trees per hectare. Social data were first coded, entered into computer and exposed to analysis by SPSS program where descriptive statistics was applied.

3. Results and discussion

3.1. Availability of NTFPs in the area

Selection of tree species supplying NTFPs was tentatively made during the reconnaissance survey. Local people perceived the pre-selected tree species as having significant importance to them. However, the most common NTFPs of tree origin in the area and their uses were also mentioned (Table 1).

Table 1: NTFPs of tree origin and their uses in Abukarshola area, South Kordofan

Botanical name	Local name	Part utilized	Uses
Tamarindus indica	*Aradeib*	Fruit, leaves	Food, drinks, medicine
Balanites aegyptiaca	*Higlig*	Fruit, bark, leaves, branches	Food, vegetable oil, soap substitute, forage, fuel-wood
Borasus aethiopium	*Daleib*	Fruit, seedlings, seeds, leaves	Food, drinks, medicine
Hyphaene thebaica	*Dom*	Leaves, fruit	Food, handicrafts, ropes making
Adansonia digitata	*Tabaldi*	Fruit, leaves, bark, seeds	Medicine, drinks, food, ropes
Gardenia iutea	*Abu gawi*	Fruit, bark	Food, soap substitute
Acacia nilotica	*Sunut*	Fruit, bark	Medicine, tannin materials
Prosopis Africana	*Abu seroug*	Seeds, branches	Local coffee, fuel-wood
Grewia tenax	*Gudeim*	Fruit	Medicine, drinks, snacks
Diospyrus mespiliformis	*Goghan*	Fruit	Food, chewing material
Ficus sycomorus	*Gumeiz*	Fruit	Food, snacks
Cordial Africana	*Gimbeel*	Fruit	Food, tannin materials
Ziziphus spina-christi	*Nabag*	Fruit, branches	Food, snacks, fuel-wood
Terminalia brownie	*Sobagh*	Bark	Tanning materials

Considering the time limit and resources available for this research, the focus of the inventory was put on tree species that are considered by the local people the most important for them for collecting NTFPs. These tree species and their relative utilized part are fruits of *Tamarindus indica*, fruits of *Balanites aegyptiaca*, leaves of *Hyphaene thebaica* and fruits and young seedlings of *Borasus aethiopium*. In general, the area is covered with natural forests, which consist of different tree species; most of the trees are thin, young and short. Results of the inventory show that the distribution of these tree species is sparse and sporadic. In the focus group discussion, people mentioned that over-cutting of trees is the main driving factor for disappearance of *Borasus aethiopium* and stunted growth, especially for *Hyphaene thebaica* and *Balanites aegyptiaca*. No comprehensive description of the forest structure was provided because the focus on the selected tree species of special importance with regards to NTFPs. However, the inventory results of the tree species under study were presented (Table 2). Only scattered trees of *Tamarindus indica* (*Aradeib* tree) are found in the study area. Clustering of the formation was not found in the entire study area or even outside the surveyed area.

Table 2: NTFPs under study

N	Botanical name	Family	Local name	Part of the tree being used	Density /ha
1	*Tamarindus indica*	Caesalpinaceae	*Aradeib*	Fruit	1
2	*Balanites aegyptiaca*	Balanitaceae	*Laloub*	Fruit	50
3	*Hyphaene thebaica*	Arecaceae	*Dom*	Leaves	24
4	*Borasus aethiopium*	Arecaceae	*Daleib*	Fruit	2
5	*Borasus aethiopium*	Arecaceae	*Halook*	Seedlings	2

3.2. Access to land and NTFPs

The results of the farm household questionnaire show that 46.7 percent of the respondents own forests (Table 3).

Table 3: Access to land and NTFPs in Abu Karshola area, South Kordofan, Sudan

Type of access	Respondent (%)
Have their own forests	46.7
Communal land	53.3
Share other's lands (especially for *Saaf* collection)	16.7
Steel from the near farm (especially for *Daleib* collection)	20.0

The average forest area per farm household is 21.4 ha. This ownership is a traditional one depending mainly upon inheritance. Fifty three percent of the respondents do not own forests even though; collection of NTFPs is a common property to all inhabitants from buffer land "locally *Gifar*". Every person has free access, throughout the year, to the natural unreserved forests and NTFPs. The results also showed that when there is agricultural production in the *Gifar* land, the area which is harvested by a family is deemed to be a family property. In this respect, that family has the right to collect NTFPs and control other people's access to that specific land. No one, apart from the family members, extracts *Saaf* from that land unless getting permission from that family. This is very obvious and easily been noticed in case of *Saaf* producing lands. For the collection of *Balanites aegyptiaca* and *Tamarindus indica* fruits, there is no specific area for collection. The same situation is applicable to *Hyphaene thebaica* leaves if it found in *Gifar* land, to which all the inhabitants have free access. For the *Daleib*, respondents in the household questionnaire and those in the focus group discussion mentioned that free access is limited to tree formation in the natural forest. Most of the nearby stands are found in individual farms, where collection needs permission. Usually landowners do not permit *Daleib* extraction, because *Halook* provides high income. Twenty percent of the respondents mentioned that, when they need *Daleib* for own consumption, they just steel it from the near farms. This can be an interpretation that little amount of fruit is needed for home consumption to the extent that the landowner does not discover that some fruits were stolen. Otherwise, those who steel will be exposed to penalty under traditional land and property laws.

3.3. Socioeconomic importance of NTFPs in the area

Results of the social survey show that, the socioeconomic importance of NTFPs is linked to other social characteristics of respondents, namely the sex, position in the household and the education level in addition to primary occupation. Additionally, an important variable in this respect is seasonal migration, which is the main factor affecting household economic activity in the area. From the 30 households selected for the study, 90% of the respondents are females; this is due to the absence of male. The consequence of this seasonal migration is the increasing load of household responsibility on women. Upton (1996) mentioned that female-headed farm households are common especially where there are employment opportunities for men in off-farm work. From the total number of 30 households surveyed, and the 27 women interviewed, 40.7% are household heads. Women when become head of households, in addition to their normal responsibilities of looking after children, being responsible for household activities that involve forest-based foods and medicine, as well as fuel-wood, they have to look for alternative sources of income for the household. The easiest source, which is accessible to every one of them and free of charge, is NTFPs in the surrounding natural forests. It is worth mentioning that, NTFPs provide different substitutes for home consumption. NTFPs also create employment opportunities for some women. The presentation of the main sources of income for the respondents, indicated in Figure 1, consolidates the economic contribution of NTFPs to household income. In this figure, 20% percent of the respondents for the household questionnaire stated that NTFPs is their main source of income while 47% depend on agriculture as main source of income and consider NTFPs a secondary and important source of income. The role of NTFPs and their economic contribution to household income is mentioned by 67% of the respondents. The rest depend on agriculture as main source of income and they have additional source of income like government employment. Social importance of NTFPs can also be expressed by the medicinal importance of some products, which is also appreciated. For NTFPs under study, 20%, 66.7% and 90% of the respondents believe in the medicinal importance of *Daleib*, *Higlig* and *Aradeib*, respectively.

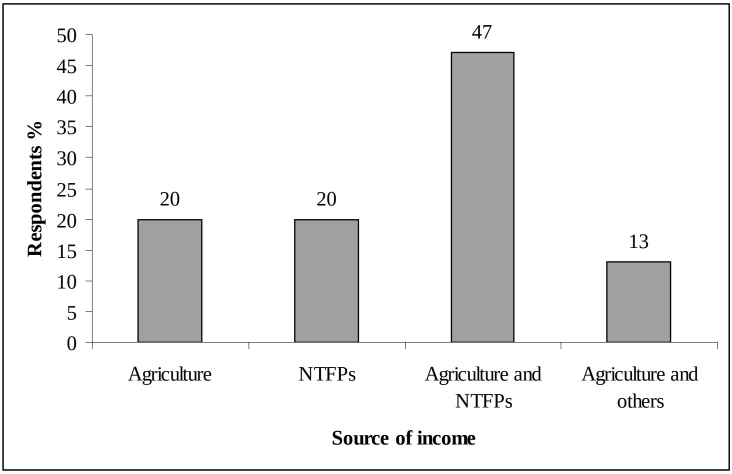

Figure 1: Contribution of NTFPs to source of income for local people in Abukarshola area, South Kordofan

During the focus group discussion, it was noticed that there is regular mid-day women group, which is mainly for *Saaf* processing "*Daffiera*" (hand-made crafts of leaves). The group meets every day in a different house making *Daffiera* and drinking coffee (*Gabana*). These groups are formed of different age categories and education levels, indicating that social relations and traditional solidarity is very strong. This consolidates the hypothesis that NTFPs has great importance in contributing to social conditions of people in the area.

3.4. Constraints to NTFPs in the area

The results of the focus group discussion about constraints to NTFPs were confirmed by the results of household interviews (Table 4). Constraints as summarized by the respondents are cutting of trees, by people from outside the area for commercial purposes, marketing of NTFPs mainly leaves (*Saaf*) products, rainfall fluctuations, grazing and civil wars which still exists in the area has limited the access to the natural forests and NTFPs. In focus group discussion, respondents mentioned that cutting of trees especially; *Borasus aethiopium* to meet the needs of towns is the main problem facing the natural forest resources in the area. Marketing of NTFPs is another problem facing those who are in this activity. The difficulty of transportation and the tough roads from production areas to market centers has added to complicate the marketing problem. Fluctuation of rainfall led people to expand on agricultural land area and of course this expansion in land is on the expense of forest land area.

Table 4: Constraints to NTFPs development in Abu Karshola area

Constraint	Respondents (%)
Tree cutting for commercial purposes	39.0
Marketing	21.8
Fluctuation of rainfall and consecutive drought periods	17.4
Grazing	13.1
Armed conflicts	8.7

3.5. Contribution of local people to develop NTFPs

Spite of the absence of clearly defined land ownership, household respondents and those in the focus group discussions mentioned that they are willing to protect and develop NTFPs (Table 5) as indicated by 67% of the household respondents. The rest 33% not contributing in the development of NTFPs because they have permanent sources of income, have sufficient land area for agriculture so they do not experience food shortage and lack of knowledge on how to contribute on NTFPs development. As indicated in the same table, the first three ways encountered in the development of NTFPs are on personal basis, because respondents (65%) were talking about their own farms; while the last two points (35%) are most important and promising view of the respondents. This is because respondents in these two points are talking about natural forests in general, regardless of land ownership. That means, those people are willing to participate in future projects concerning development of natural forests and NTFPs in particular. In this context, thinking of any project in the area should consider land ownership high priority to guarantee project success. Therefore, determination of land ownership even under communal control is a key issue to NTFPs development in the area.

Table 5: Contribution of local people in the development of NTFPs in the area

Way of contribution to development of NTFPs	Respondents (%)
Protecting their own farms from grazing	20
Protecting their own farms from tree cutting	30
Value added of NTFPs (dying *Saaf*)	15
Preventing outsiders from tree cutting and charcoal making in forests	25
Inform forest officers about any illegal practices in the forests	10

4. Conclusion

Abukarshola Rural Council "the study area" is a region of high population pressure; there the management of natural forests has been left to nature. This study looks at available potential, local use and management system of selected NTFPs collected from these forests. It highlight the importance of understanding how much of these NTFPs is available in the area and how local people utilize these products. With regards to the potential, the density of tree species under study is only one tree per hectare for *Tamarindus indica*, 50 trees/ha for *Balanites aegyptiaca*, 25 trees/ha for *Hyphaene thebaica* and 2 trees/ha for *Borassus aethiopium*. This density of trees is much less than the expected because the area is classified as being rich in tree species that produce NTFPs. There is no regulations governing which product should be taken at which time and in which amount; and all inhabitants have free access to all types of NTFPs from natural unreserved forests. Therefore, the existing potential would not be enough for future generation with the prevailing environmental factors and commercial utilization of these forests for NTFPs, fuel-wood and charcoal. NTFPs contribute to both social and economic conditions of people in the study area. Under certain conditions, local people can take some kinds of spontaneous action to improve natural resource management. This is clear in the case of *Saaf*, which proved to be an important source of income generation for most of the households. In addition to that, people in the area showed willingness and interest to protect NTFPs by protecting trees from cutting and inform forests administration about illicit activities that take place in the natural forests. To enhance the role of NTFPs, the study recommended that promotion of smart partnership between local communities and private sectors depending on dialogue, transparency and respect is needed.

References

El Tahir, B.A., Fadl, K.M. and Fadlalmula, A.D. (2010) Forest biodiversity in Kordofan Region, Sudan: Effects of climate change, pests, disease and human activities. *Biodiversity* 11 (3 & 4), 34-43.

FAO (1995) Non-timber forest products: topical palms. Non-wood forest products No. 10. FAO, Bangkok.

FAO/SIDA (1987) Restoring the balance: women and forest resources. FAO/SIDA.

Geller, S., McConnell, R. and Rahamtalla, I. (2006) Linking national forest programmes and poverty reduction strategies, Sudan. FAO: Rome, Italy.

Gumaa, Y.O.A. (2011) Contribution of local-level trade in non timber forest products to rural development in Rashad locality of Nuba Mountains, Sudan. PhD Dissertation, Fakultät Forst-, Geo- und Hydrowissenschaften, TU-Dresden.

Mander, M., Mander, J. and Breen, C. (1997) Promoting the cultivation of indigenous plants for markets. Experiences from KwaZulu-Natal, South Africa. In Leakey, R.R.B., A.B.

Temu, M. Melnyk and P. Vantomme, eds., Domestication and commercialization of non-timber forest products in agroforestry systems. FAO, Rome, Non-wood Forest Products , 104–109.

Upton, M. (1996) The economics of tropical farming systems. Cambridge University Press.

Assessment of Marketing System and Channels of Gum Arabic Commodity in Main Auction Markets of North Kordofan State-Sudan

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Abstract

This study was conducted during 2007/2008 in Elobied, Elnuhoud and Umrawaba auction markets as the biggest markets of Gum Arabic in North Kordofan. It assessed the performance of gum Arabic marketing system as the main commodity among other Non Timber Forest Products (NTFPs). Two sources of data were used. Primary data was collected by a structured questionnaire and direct interviewing with gum Arabic traders. Non- probability sampling technique was used to select forty respondents as a sample size. Secondary data was collected from pertinent sources. The data was analyzed by descriptive statistical method to address the socio-economic characteristics of the traders. Simple, multiple regression and correlation analyses were also used to estimate the relationships among different variables. The main findings of the study are: seventy seven percent of the Gum Arabic traders preferred liberalization to concession. Gum Arabic Company had not fulfilled its marketing obligations in the production season 2007/2008. In addition, the incidence of processing companies with financial aptitude had offered higher buying prices than the announced floor prices and paid in cash. The study recommended full liberalization of gum arabic commodity marketing and establishment of a Commodity Council for Gum Arabic commodity as an independent body to co-ordinate and promote Gum Arabic Marketing.

1. Introduction

Sudan is the world's largest producer of gum Arabic, which is one of the four important agricultural export commodities from Sudan, beside livestock, cotton and sesame. The government desist the intervention in the marketing of all agricultural exports, except gum Arabic is the only one of which government control remained (World Bank, 2007).

The system of gum Arabic marketing abroad witnessed many changes since commence of gum Arabic trade in 1820 which is considered to be the beginning for the expansion of gum Arabic trading in the Sudan. As in 1922 free trade policy was introduced into the economy. It experienced various problems such as absence of organization or mechanism to control and protect the producers, decrease foreign currency proceeds due to severe competition in the international markets. . In 1969 the government of the Sudan granted an exclusive concession to export of raw gum Arabic to the Gum Arabic Company (GAC).This policy had three main objectives: a) to exercise market power, as Sudan at that time was producing 80% of the global gum traded, b) to guarantee production and protect producers through implementation of floor price, and c) to preserve the environment by maintaining the high demand for gum which was expected to help in expansion of Acacia cover(Karama,2002). The concession of the GAC as a sole exporter of gum was abolished and restored two times first one was restored by the president in 1992 and the second one was restored by the parliament in August 2001. Since 2002, GAC was subjected to criticisms from certain companies and the Forestry National Corporation. Again the controversy of liberalization as a model for gum Arabic marketing evolved (World Bank, 2007). This study assessed the performance of gum Arabic marketing system as the main commodity among other Non Timber Forest Products (NTFPs).

2. Materials and Methods

2.1. Study area: Elobeid crops market

Elobeid market is one of the earliest crop markets in Sudan, since its establishment in 1905; it has been the largest market for gum Arabic market in the world. The area of the market is about 1768.8 square meters, 141.5 meters long and12.5 meters wide. In 1905 its position was in the large market and the operation sale was by barter system (ECM, 2006).

The Auction operation System in the market

The Auction operation system procedures include the activities of the following market administration's Sections:

The Seizing Section: It aims at a) The preparation of places for different crops landing, b) Submission of marks to facilitate the inspection of the crops by traders and the agents and c) Registration of various crops in the notebook "Musseir book" to be presented for marketing in the auction hall.The Auction operation: The Auctioneer usually begins with gum Arabic - sesame -groundnuts - hibiscus– watermelon seeds and Sanammaka. The producers or the producers' agents have the rights to sell their crops if the market prices are rewarding and vice versa if they are not find the appropriate price will recorded the word (Bait) as a sign for excluded crops from the auction and to be displayed on the second day.Elgubbania Section: This Section specialized in weighing of the crops in the auction market.

Accounting services: The purchases of all traders accounted and registered daily. Each trader has a separate page statement (quantities in *kuntar* and the amounts owed to be paid to the producers, the imposed fees to each crop from services, marketing, and the imprint or state stamp). The interior Paying: Collection of fees from the merchants with financial receipts. Finally passing licenses: To obtain the permits for trucks passing, including all the statements about the loaded crops (ECM, 2006).

2.2. Primary data collection

Cross- sectional data were collected by means of a structured questionnaire and direct interviewing of the gum Arabic traders in Elobied, Elnuhoud and Umrwabba auction markets, beside some selected village markets in North Kordofan State during the season 2007/2008.

2.3. Secondary Data collection

This data was collected from related secondary sources such as Gum Arabic Research Center-University of Kordofan, Bank of Sudan - Elobied branch, Warm Seas Company. (Elobied industry), Gum Arabic Company, Sudanese Standards and Metrology Organization (Elobied office), other relevant sources include papers, Journals, researches and previous studies.

2.4. Sample Frame

The main focal study area is Elobied crop market, but to support the assessment of the gum Arabic marketing system, *Elnuhuod* and *Umrwabba* auction markets beside some selected village markets were considered too. **Sample Design:** A well designed sample was done by selection of respondents from different types of gum Arabic traders in the sample, including the village traders, agents and secondary traders. **Sample Size:** a non- probability sampling technique was used to select forty respondents (Traders) as a sample size.

2.5. Data Analysis

The data was analyzed by using statistical package of social science (SPSS) in terms of descriptive statistical analysis (frequencies and percentages) for the socio-economic characteristics of the traders.

Regression analysis was used to assess the relationship between the dependent and independent variables.

Regression methods

Simple Regression Model: In this regression analysis there only one factor that affect the dependent variable (Johnson and Buse, 1987). Its formula as follows: $Y = b_0 + b_1 x + e$

Where: Y= the dependent Variable, x = the independent variable, b_0 = intercept, b_1 = regression coefficient, e = the disturbance term.

Multiple Regressions

It consists of two or more independent variables, it is considered as a logical extension of the simple regression model (Bower, 1982). The general equation of multiple regression models is written as: $Y = b_0 + b_1 x_1 + \ldots\ldots + b_n x_n + e$

Where: Y = the dependent Variable, $x_1 \ldots\ldots x_n$ = the independent variables, b_0 = intercept, $b_1 \ldots b_n$ = regression coefficients, e = the disturbance term. The coefficients represent the change in the value of the dependent variable for a unit in one independent variable, assuming other independent variables being constant.

The test of hypotheses

The t-test: T-test is related to individual coefficient in the regression models. It is used to test whether each coefficient is significantly different from zero or not. T- Value is calculated by dividing the regression coefficient of the variable by its standard error. The computer software regression package gives the t- value to the probability of this coefficient being significantly different from zero.

3. Results and Discussion

3.1. Experience of traders in gum Arabic markets

As shown in table (1) about 92%of the respondents had an experience in gum Arabic trading extending from (2-30) years, while only 8% had over 30 years. This character is expected to be the determinant factor in evaluation and assessment of gum Arabic marketing system, because most of them have been engaged in gum Arabic marketing and transactions with GAC more than 15 years.

Table 1: Experience of traders in gum Arabic markets

Experience (years)	Valid Percent (%)	Cumulative Percent
0-10	40.0	40.0
11-20	35.0	75.0
21-30	17.5	92.5
31-40	7.5	100.0
Total	**100.0**	

Source: field survey (2008)

3.2. Distribution of gum Arabic traders by type of trade

As shown in table 2, about 18% of the target traders were village traders, 52% were agents, 18% were secondary traders and 12% were both secondary traders and agents. Village traders were the first traders who buy gum Arabic commodity directly from the producers and transport it to the markets for sale to secondary traders or to auction markets. Agents are mediators who have licensed offices inside or outside the auction markets. They enter the auction market and mediate between buyers and sellers of gum Arabic. Secondary traders are the large traders who buy gum Arabic commodity either directly from auction markets or through agents and often from village traders. They store gum Arabic commodity for speculation of higher prices, or deliver their purchases to GAC according to its declared annual marketing policy.

Table 2: Distribution of gum Arabic traders by type of trade

Type of trade	Valid Percent	Cumulative Percent
Village trader	17.5	17.5
Agent	52.5	70.0
Secondary trader	17.5	87.5
Agent + Secondary trader	12.5	100.0
Total	**100.0**	

Source: field survey (2008)

From table 2, especially in the main auction markets cities, the majority of gum Arabic traders were agents. They enter the stock market as representatives to producers as a buyer, or as a seller for those who purchase gum Arabic product. The number of local secondary traders who buy the natural gum Arabic from the markets directly or through the agents decreased either for their weak capital, or to avoid the hazards and risks involved in trading of gum Arabic. From the field survey observation, producers, village traders and middlemen or brokers transport the gum Arabic product to auction markets. The buyers` agents purchase gum Arabic commodity for processing companies, business men and other commercial companies. They rarely buy for commercial banks.

The source markets for collecting of gum Arabic commodity were Elobied, *Elnuhoud* and *Umrwabba*. Some of traders deal with all three markets and others buy from one or two markets depending on their capital and transactions size. The majority of traders had marketing relationship with producers, which start before tapping and after picking. Another group starts their relationship only when buying gum product in the market. The relationship takes place either in form of tapping finance or in form of buying the product. The relationship for the majority of traders takes the form of gratuitous loan, followed by sharing and finally by Salam and *Shail* systems. Payment is made either in cash or cash plus foodstuff. Also from the field survey observation there were no relationships between the (GAC) and the producers. GAC did not provide any of the basic needs services (water drilling) or any other supports to producers' areas, which it used to provide in the previous years. The traders traded in other crops such as groundnuts, sesame, *kerkady*, watermelon seed and *senamaka*. They traded in different quantities according to their availability in the markets. *Elnuhoud* market is distinct by groundnuts, *kerkady* and watermelon, whereas *Umrwabba* is famous by sesame, *kerkady* and groundnuts. In Elobied market, all the crops were abundant because of its strategic commercial position. So the crops flow into the market from all production areas of Great Kordofan State.

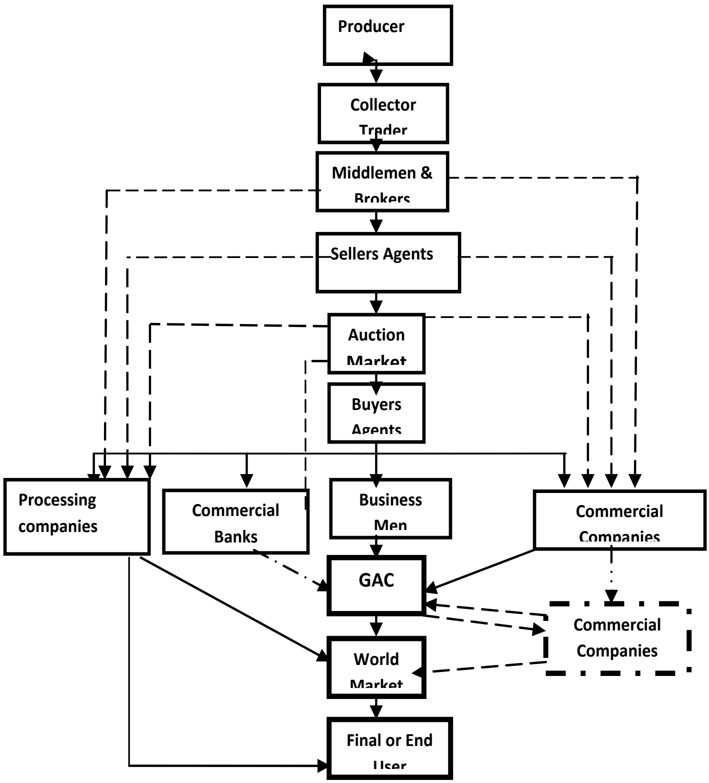

Figure 1: The marketing channels of gum Arabic commodity, Source: (Field survey 2008)

3.3. Financial sources in support of gum Arabic trade

The financial sources supporting gum Arabic traders included self financing, commercial banks, processing companies. About 25% of the respondents finance trade from their own resources. However most of them were village traders, so they didn't constitute an important financial source for their small financial scale. About17% had financial support from processing companies, 15% from commercial banks, and the remaining had among more than one source. Financial support from GAC was absent compared to previous years.

3.4. Distribution of agents by buying of gum Arabic commodity

About 28% of agents buy gum Arabic product for processing companies in return for certain commission. The processing companies represent an important source for purchasing gum Arabic product by virtue of their financial capacity and liquidity with cash for payment of transactions. The rest were distributed among the other sources such as business men, banks or more than one source simultaneously. Of all agents there was no one dealing directly with GAC. About 32% of the agents did not have any relation with either village traders or basic traders.

3.5. Frequency of GAC refusal of buying gum Arabic from traders

About 35% of traders indicated that GAC had refused from 1-5 times, while 12%of traders had more than 5times refusals. About 53% of the traders indicated that they did not have relation with GAC. These results reveal that GAC had neglected its obligation towards buying gum Arabic from local traders in the producing areas.

Table 3: Frequency of GAC refusal of buying gum Arabic from traders

GAC refusal frequency	Valid Percent	Cumulative Percent
No relationship	52.5	52.5
1-5 times	35.0	87.5
more than 5 times	12.5	100.0
Total	**100.0**	

Source: field survey (2008)

3.6. Opinion about responsibility of GAC in full monitoring of gum Arabic marketing in Sudan

Table (3) explains the opinions of traders about the role and responsibility of GAC towards gum Arabic marketing. About 85% of gum Arabic traders indicated that GAC did not have any supervision in any form. However, about 15% of the traders indicated presence of GAC monitoring and supervision role based on their previous experience.

Table 4: Opinion about responsibility of GAC in full monitoring of gum Arabic marketing

Opinion about responsibility	Valid Percent	Cumulative Percent
Yes	15.0	15.0
No	85.0	100.0
Total	**100.0**	

Source: field survey (2008)

3.7. Personal opinion of gum Arabic traders about feasible gum Arabic marketing system

Table (4) reveals the personal opinion of gum Arabic traders on this issue according to their experience in marketing of gum Arabic. About 77% of the respondents chose liberalization system and only 23% who advocated the concession system of GAC.

Table 5: Personal opinion of Gum Arabic traders about feasible marketing system

Personal opinion	Valid Percent	Cumulative Percent
No response	2.5	2.5
Concession system owned by GAC	20.0	22.5
Liberalization system	77.5	100.0
Total	**100.0**	

Source: field survey (2008)

3.8. Argument on the Liberalization of Gum Arabic versus concession

Several arguments were given as follows:

Liberalization policy gives opportunity to some companies to compete with the monopolistic GAC with respect to the supply and the demand of the commodity. Liberalization opens new exports prospects to producers and traders. It also provides liquidity in the markets to various areas of production. Liberalization motivates local companies to engage with foreign companies that possess capital and of marketing experience. On other hand the weakness of financial capacity for GAC was revealed by its absence from the market and the entry of other competing firms with financial ability. Those competitors offered higher buying prices than the floor price, and paid cash for their purchases. Besides those competitors were present in areas of production from the beginning of season, and were buy any produce for sale, also monopoly leads to lower prices of gum Arabic product, because Gum Arabic Company buys at low prices and sells at high prices globally, but these prices are not reflected to the domestic producers. As a conclusion gum Arabic marketing was surrounded with many problems that need solution by the intervention of Federal Government. Taxes and levies that imposed on gum Arabic commodity should be reformed to facilitate easy access to foreign markets. The majority of markets traders preferred liberalization to concession when evaluating marketing of gum Arabic system in North Kordofan auction markets. Based on the field survey and discussion with experienced gum Arabic traders in the biggest production areas in Sudan, Gum Arabic Company lately failed to fulfill all the obligations and commitments of concession. All the justifications of liberalized market choice represent the dominating opinion regarding changing the present system of gum Arabic marketing in the Sudan. On the other hand those who advocate the continuity of monopoly based their opinion on the performance of GAC in the past.

References

Bower (1982) Statistic for Economist. Macmillan L. TD.

Couteaudier, T.Y. (2007) Export Marketing of Sudanese gum Arabic, Multi Donor Trust fund-National, Technical Secretariat, the World Bank, Khartoum, Sudan.

Elobied crops market Administration (2006) Historical Background, the Past, the Present and the Future. Sheikan Locality, North Kordofan State.

GAC (1969) Memorandum and articles of Association and Amendments Khartoum Sudan.

Johnson, M.B. and Buse, R.C. (1987) Econometric: Basic and Applied-Mehillan publishing company. New York and London.

Karama, M.M. (2002) Gum Arabic Marketing Issues: Marketing Model, Buffer-Stocking, processing & Financing, paper presented by international workshop on promotion of gum Arabic production, processing and marketing (2002) Khartoum, Sudan.

Kennedy, Peter, K. (1985) Guide to econometrics. Cambridge Massachusetts.

Kmenta, J., Elements of Econometrics, Macmillan P. C.

Contribution of NTFPs to the Sustainable Livelihood of Local Communities in Um Rauwaba Locality, North Kordofan, Sudan

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Abstract

This study investigated the contribution of some Non Timber Forests Products (NTFPs) to the sustainable livelihood of local communities in Um Rauwaba Locality. It identified the uses and importance of some NTFPs and to highlighted constraints and measures of risks confronting their investment. Primary data was collected through interviewing with local people and group discussion with Forests National Corporation (FNC) staff, while secondary data includes FNC files, annual reports, project documents, and previous studies conducted in the same site. The main findings are; the majority of the respondents (70%) rely agriculture as the main source of income besides collection of NTFPs. Handicraft activity based on NTFPs represents the second important for income generation. About (4.7%) of the respondents rely solely of NTFPs for income generation. The main NTFPs collected included fruits of Aradaib (Tamarindus indica), Garad (of Acacia nilotica), Lalob (of Balanities aegyptiaca), Goungolaiz (Adansonia digitata) and Sinamaka (pod of Cassia senna). Some NTFPs have with limited uses. NTFPs are collected either for household consumption or for marketing. For household consumption, NTFPs are collected from distances varies between 1 – 2.5km, while for trading collectors may cross devastating areas for

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sake of collecting considerable amount of NTFs. Hand picking, tree climbing, sticks and stretched mats are used in NTFPs collection. Also NTFPs do not contribute significantly to the budget of the (FNC). NTFPs are liable to damage by birds and insects, therefore their prices are determined by these factors. The FNC has not exerted efforts to inventor the resource or to assess the natural regeneration of the NTFPs producing trees. FNC has to provide the people with extension services and has to give importance to the NTFPs activity.

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1. Introduction

Forest produces a great variety of goods and services for people. Thus forest has value to people and contributes to meet human needs in a number of ways. The contribution occurs through either direct or indirect use of the forest. Forests were recognized as rich reservoirs of many valuable biological resources, not just timber. Non- Wood Forest Products (NWFPs) emerged as an umbrella term to recognize the products derived from these various forest resources as group. The scope of NWFPs was proposed to be defined as all goods of biological origin other than wood as well as services derived from forests and allied land use. NWFPs are an integral part of the livelihood of 500 millions who live in or near tropical forest that cover 20 % of the world land mass (Cfan 1992).

Examining household use of NWFPs it were found that these products were effective in both providing gathered foods that contribute to food self sufficiently and hence food security and saleable products that could supplement income needed to purchase food (Arnold,1995). In supplementing household agricultural production, they are particularly important in reducing shortages suffered during "hunger period" of agricultural cycle. They help to even out seasonal fluctuation in availability of food and often contribute to essential inputs for household nutrition. They are also valued as compartments of social and cultural identity although these uses and values vary enormously from one area to another. Environment dimensions of (NWFPs) cover a wide range of roles and aspects. In fragile ecosystems (NWFPs) activities hold to prospects for integrated forms of development that yield higher rural incomes and conserve biodiversity while not competing with agriculture.

2. Objectives of the research

The general objective of this study to investigate the contribution of NWFPs to the sustainable livelihood of household in food security, confines its focus in El Rahad in North Kordofan State. The study covers some NWFPs excluding Gum Arabic.. The specific objectives of the research are:

- To highlight the impacts of reliance on some NWFPs for income generation.
- To determine the time calendar of some NWFPs in terms of time of collection and marketing.
- To identify the different stakeholders engaged in NWFPs collection and marketing.
- To identify the uses and importance of NWFPs.
- To determine measures of risks confronting development of NWFPs markets.

3. Study area

Location

North Kordufan State lies between Latitudes 11° 15´ - 16° 45´ N, and longitudes 27° 50´ - 32° 15´ E. Fig (3.1) shows the map of the study area. The total area of the state is 24.612 million hectares (Planning and Information Administration 2006)

Administrative Structure

North Kordufan State is composed of nine localities. . Um Rawaba lies in the eastern part of North Kordofan State, between Latitudes 12°

30´ - 12° 45´ N, and between Longitudes 30° 50´ - 31° 45´ E. The area of the Locality is 24610 km^2, 30% of this area is used for agricultural practices. The main tribes in the locality are Gawamaa tribes who intermingled (intermixed) with some other tribes in living and breed (Planning & Information Administration 2006).

Climate

North Kordufan State is characterized by different and numerous climatic zones (Planning & Economics Admin. 1991):

- desert area: Rain fall amount is low (Less than 100 mm. per annum)
- semi-desert area: Rainfall amount is between 100-225 mm. per annum.
- arid zone: Rainfall amount is 225-400 mm. per annum.
- semi-arid zone: Rainfall amount is between 400-750 mm. per annum

Rainfalls are seasonal, erratic in quantity and distribution. The rainy season starts in May and continues to October with peak in August (UKRDP 2001. The temperature is high all years around except during wintertime (Nov. – Feb. – March) maximum temperature is about 42 ◦c during May.

The study area is highly affected with the patterns of climate change and variability, particularly frequent drought and sporadic nature of rainfall. Drought is a common unwelcome visitor to the study area and it induces several negative impacts. These impacts are apparent in the period between 1983 and 1992, which dexterously affected the natural resources in the State.

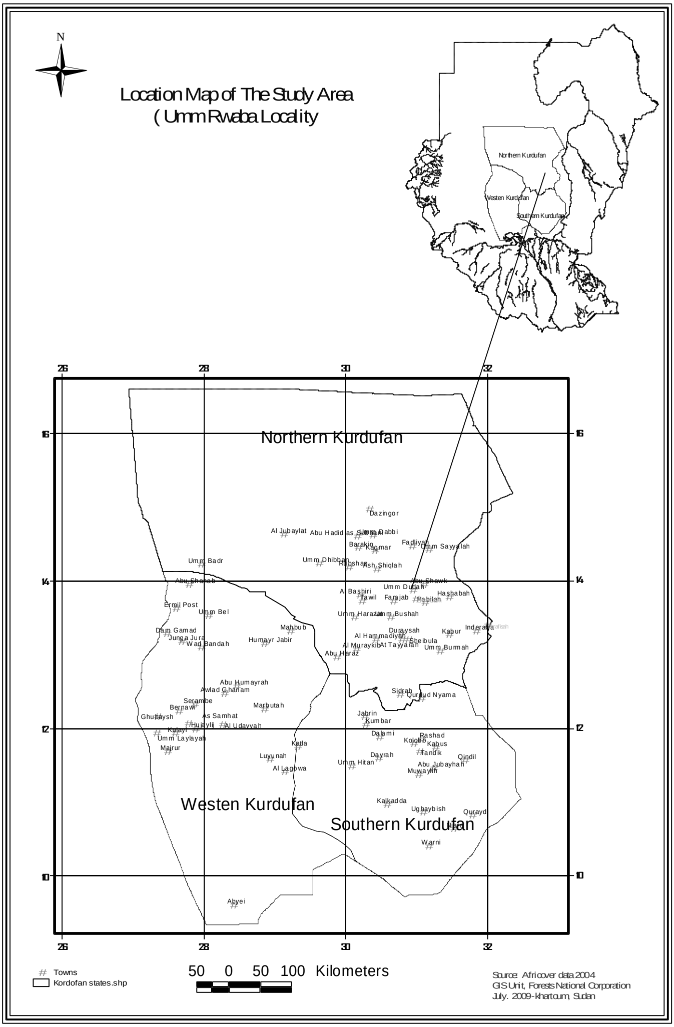

Figure 3.1: Location Map of the Study Area (Um Rawaba Locality)
Source: FNC 2004

Soil Type

Soils in North Kordofan are divided into four major groups (Classes): sand dunes, the "Gardoud" soils, the sediment soils in Khor abu habil basin and the "wadis", and lastly the cracking clay soils group. Um Ruwaba province lies within the goz belt and the clay soils are found in the southern part of the district and between sand dunes.

Vegetation

Acacia senegal (Hashab) is one of the dominant species that occur naturally in the State. The most dominant associated tree species are: Acacia raddiana (sayal), Faidherbia albida (haraz), Adansonia digitata (tebeldi), Zizphus spinachristi (nabag), Balanites aegyptica (heglig), Acacia millifera (kitir), Boscia senegalensis (mukhit), Cadaba flandulosa, Cadaba rotundifolia (kumut), Tamarinduos indica (aradieb), Azadirachta indica as plantation tree (Neem) and Calotropis procera (usher). The total area of the North Kordofan State conserved forests are about 7937506.387692 hectares while the total conserved forest of Um Rawaba locality was 35645.904 hectares, (FNC, 2008).

Population

The total population of North Kordofan State was 2424450 according to the last census 2007, while the population of study area (Um Rawaba Locality) was 583087 according to 2007 (Statistical Census, North Kordofan, 2008). The rural population in the state represents 67% of the population and the urban population percent is 13% and the nomads' equals 20% (FAO, 2006). Table (3.2) shows the Population of the study area.

Table 3.2: Population of the Study Area

Locality	Administrative	Population 2007
Um Ruwaba	Um Rawaba Town	53243
	Rifi and Wasat Um Rawaba	176829
	North Um Rawaba	120973
	Wad Ashana	90377
	Rifi and El Rahad Town	141664
Total		**583087**

Source: North Kordofan Census 2007

Water resources

Rainfall is the main source for water in the NKS .

Economical activities

Agriculture is practiced as a major activity for living beside animal herding and commerce

4. Methodology

This chapter includes description of scope of research, the target group and sample selection. Moreover, the data collection instrument (questionnaire) is also described in forms of its construction, validity and field-testing as well as the procedures and methods employed for data .

Two types of data were used to collect the necessary information, namely, primary and secondary data. The source of the secondary data includes FNC files, annual reports, project documents, and previous studies conducted in the same site. The primary data were principally collected through interviewing to investigate the local peoples perception towards their reliance on the NWFPs in the study area. More specifically, the data cover the main items of the objectives of the study mentioned in chapter 1.

Selection of Study area

Moreover, due to the acute poverty of the inhabitants of the state, consumption of NWFPs is considered as a source for diet diversification and self satisfaction. This reliance has serious impact on the sustainability of the resource. Accordingly, Um Rawaba Locality was selected as a case study since the local markets trade on NWFPs.

Selection of Villages

Five villages were selected from El Rahad Adminstrative Unit. Villages were classified into three categories (large, medium and small villages) based on the number of households. The selection of villages in each category was based on random sampling .

Table 4.1: Selection of villages and households

Selected villages	Range of households	
Abu Teleh Omer Eradieb a Elmahata	24 – 597	Small villages
El Windishig Um Draba El Tahir	598 – 1195	Medium villages
Goz Bashara.	1196 – 1816	Big villages

Selection of the Respondents

The household is selected to be the basic unit of analysis for this study. The primary data was collected from the surveyed population using the questionnaire as a tool for face-to face interview. A structured questionnaire was used for the household respondents where the questionnaire included questions covering the following key areas. Demographic questions about the respondents These questions are followed by questions about land ownership, the cultivated crops, and the sources of income, in addition to information about the type of the activities practiced by the respondents. Data on the NWFPs was collected using questions developed to obtain information about, the NWFPs prevailing in the study area and their sources at the disposal of the local people .

Other sources of primary data

Group discussion methods were used in this research with FNC personnel at the study area.

Construction of the questionnaire

The construction of the questionnaire was made according to the guidance of FAO (1985). The suggestion of the supervision as well as ideas of other experts in the field of study helped to reach the final format of the questionnaire. The following guidelines of Burchinal (1986) were also given special consideration in the construction of the questionnair.

Organization of data

The first step involved was obtaining permission from local authorities before conducting the survey

Statistical analysis

The statistical analysis was commenced through exploratory manipulations of the data obtained in the study area .This process was accomplished by critically examining the data through the use of simple tables and selected cross-tabulation which allows tentative answers to many of the question being asked in the survey.

5. Results and Discussion

Regarding the production of NWFPs, Fig (5.1) shows the total amount of NWFPs collected from the study area during the period 1997 – 2008.

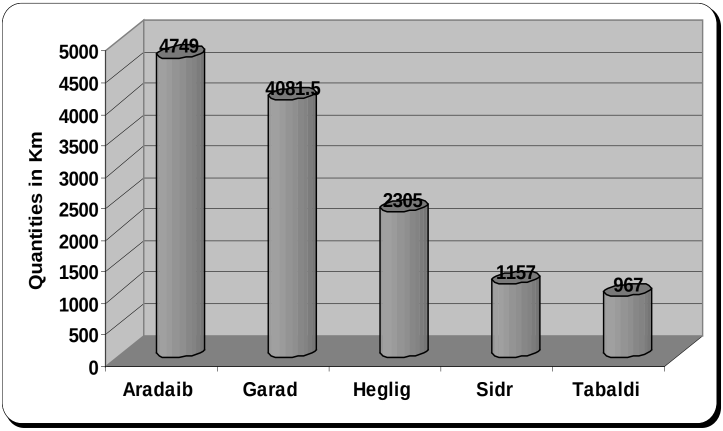

Figure 5.1: Total amount of NWFPs collected from the study area during 1997 – 2008

Table 5.6: Collectors of NWFP and purposes of collection

Collection of NWFP			Purpose of collection		Study areas
Children	Women	Men	Marketing & consumption	Consumption	
30	50.0	20.0	60.0	40.0	Abu Teleh
16.7	58.3	25.0	54.5	45.5	Aradiba El Mahta
12.5	56.3	31.3	60.0	40.0	Shig El Windi
0	86.4	13.6	85.7	14.3	Um Draba Eltahir
9	81.8	9.1	81.8	18.2	Goz Beshara
10.6	**73.1**	**16.3**	**74.3**	**25.7**	**total**

Table (5.7): Royality paid for some NWFPs in the study area(1997-2008) (SDG

Year	Laloub	Gonglize	Aradaib	Nabg	Sinamka	Garad	Saaf	Other
1997	-	-	1268.6	187	-	11.250	-	
1998	-	-	-	-	-	-	42	
1999	60	841	-	135	231	42	-	
2000	-	54	685	-	-	420	-	
2001	379.1	889	525	312	-	358	87	
2002	159	42.5	65	294.3	7	61	236	
2003	27	-	-	35	-	-	112	
2004	35.5	-	-	10	-	190.95	1427.4	
2005	93	233	-	228	-	-	-	
2006	152	-	141.5	-	-	-	144	
2007	2685	152	178	136	-	42	297.2	
2008	1831	81	-	100	69	-	507	30
Total	5421.6	2292.5	2863.1	1437.3	307	1125.2	2852.6	30

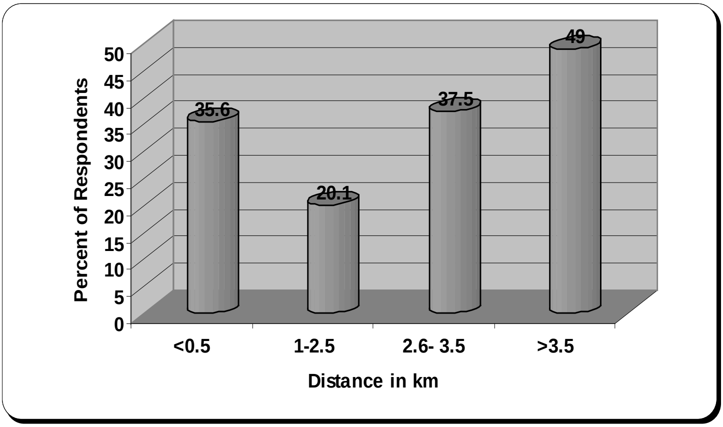

Figure 5.2: Distance traveled for NWFPs collection

Table 5.8: suitable time for the collection of NWFPs in the study area

All day	Evening	Morning & afternoon	Afternoon	Morning	
30	20	10	40	0.00	Abu Teleh
50	0.00	0.00	50	0.0	Aradiba El Mahta
6.3	0.00	0.00	68.8	25	Shig El Windi
4.5	4.5	22.7	4.5	63.6	Um Draba Eltahir
0.00	4.5	25	13.6	56.8	Goz Beshara
10.6	**4.8**	**16.3**	**26.9**	**41.3**	**Total**

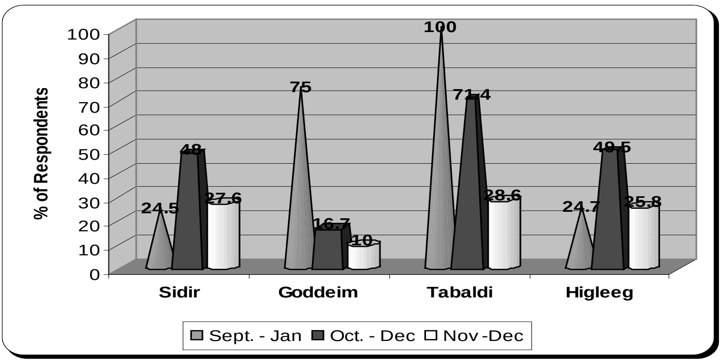

Figure 5.3: Time calendar for the collection of some NWFPs in the study area

Table 5. 9: Methods of NWFP collection in the study area

Indigenous knowledge of collection		Method of NWFP collection				
By training	Heritable	Direct from ground	Hand picking	Mat	Stick	
0.00	100	30	50	10	10	Abu Teleh
16.3	83.3	33.3	50	0.00	16.7	Aradiba El Mahta
0.00	100	31.3	68.8	0.00	0.00	Shig El Windi
4.5	95.5	57.1	42.9	0.00	0.00	Um Draba Eltahir
6.8	93.2	63.6	36.4	0.00	0.00	Goz Beshara
5.8	**94.2**	**50.5**	**45.6**	**1**	**2.9**	**total**

Table 5.10: Marketing of NWFP in the study area

Marketing of NWFP		Markets of NWFP			
Women	Men	El Rahad market	Nearby village	Village	
70	30	50	30	20	Abu Teleh
75	25	33.3	8.3	58.3	Aradiba El Mahta
81.3	18.8	62.5	12.5	25	Shig El Windi
100	0.00	81.	4.8	14.3	Um Draba Eltahir
95.5	4.5	59.1	15.9	25	Goz Beshara
89.3	**10.7**	**60.2**	**13.6**	**26.2**	**total**

Table 5. 11: Transportation and cost of transportation of NWFP at the study area

Transportation cost (SDG)			Transportation of NWFP			
<15	7-15	1-6	Hand & head load	Lorry	Donkey	
0.00	0.00	100	20	40	40	Abu Teleh
16.7	0.00	83.4	36.4	27.3	36.4	Aradiba El Mahta
25	25	50	80	6.7	13.3	Shig El Windi
7.1	57.1	35.6	33.3	57.1	9.5	Um Draba Eltahir
0.00	22.2	77.7	38.6	27.3	34.1	Goz Beshara
5.1	**25.5**	**69.5**	**41.6**	**31.7**	**26.7**	**total**

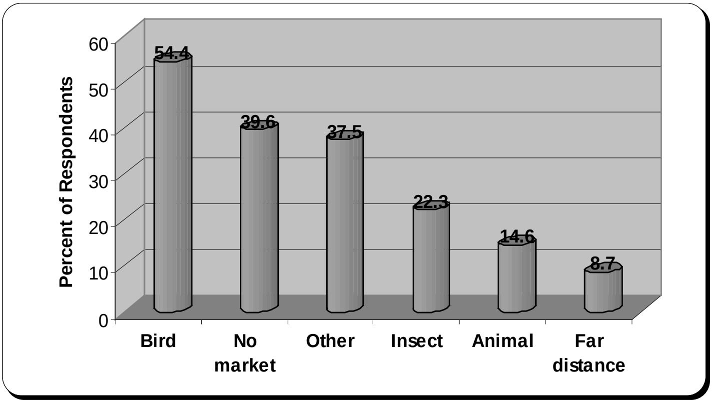

Figure 5.5: Factors influencing NWFP collection and marketing in the study areas

6. Conclusions and Recommendations

6.1. Conclusions

- The interviewed sample showed all the age groups (young, youth, mature and old) an indication of lack or low level of migration.
- The majority of the respondents (71.1%) is either illiterates or had preschool education (Khalwa).
- The family size is relatively big in the study area
- The majority of the respondents rely on agriculture as the main source of income besides collection of NWFPs.
- Generally, the quantity collected is relatively low.
- The main NWFPs consumed at the household level or tradable are; Aradaib, Garad, Heglig, Tabaldi, Sinamaka and Dom. .
- The majority of the respondents collect the NWFPs from their farms.
- Women remain the main collector of the NWFPs.
- Although the majority of the respondents collect NWFPs either for trading or consumption, it seems that collection of these products is mainly for household's consumption.

- The most tradable NWFPs are heglig followed by Aradaib, Saaf and Tabaldi. Garad and Nabag showed a moderate level while sinamaka and some other NWFPs showed a lower level.
- The bulk of NWFPs is collected from the farms, while 20.1% of the respondents collect the NWFPs from a distance of 2.6 – 3.5Km.
- Suitable time for collection of NWFPs, about 26.9% of the respondents mentioned the afternoon as the suitable time for collection of NWFP, while 10.6% of the respondents stated that it depends on the leisure time of the collector where all the day long is suitable for collection of NWFP. Collection of NWFP at morning is preferred by a high percentage of the respondents (41.3%).
- The period between Octobers - December, showed high collection of Tabaldi, Heglig and Sidir fruits.
- Almost half of the respondents collect the NWFPs directly from beneath the trees (from the floor). Other methods include hand picking, sticks and mats.
- Some respondents tend to collect the fruits before ripening, particularly Tabaldi fruits to avoid the damage of fruits by birds and insects. Moreover, some respondents collect fruits before ripening due to the competition among the collectors.
- Local people in the study area have limited channels for the disposal of their collected NWFPs. Some respondents (60.2%) transport their collected NWFPs to the principal cities in the study area (El Rahad and EL Simaih markets) due to possibility of attaining reasonable prices.
- Some respondents prefer to dispose their collected NWFPs at the village markets (to brokers or the village merchants) to escape the cost of transportation of the products to the principal cities.
- The majority of the respondents (89.3%) stated that women usually take the responsibility of marketing of forest products.
- For small collected quantities of NWFP, transportation is usually through hand or head load as asserted by 41.6% of the respondents. While traders use different methods like animal carts, donkeys and trucks.

- Birds and insects are the main menaces that endanger investment in NWFPs.
- Marketability of NWFPs is influenced by the quality of the NWFPs.
- The local people perceive NWFPs in different ways. The majority of the local people rely on these products as food, while a considerable proportion relies on these products for folk medicine. Few local people rely on NWFPs for income generation.
- All the FNC personnel asserted that there is no effort exerted by the FNC for inventorying NWFPs producing
- No attempts were made by the FNC for assessing the regeneration of NWFPs producing trees at natural and reserved forests. Also there was no any study was made to investigate the seed bank at the study area moreover, at the nurseries, most of trees producing edible fruits are not raised in high quantities

6.2. Recommendations

- The FNC should attempt to give special consideration for the NWFPs producing trees in terms of their regeneration, protection and inventory
- Extension services provided by the FNC should guarantee the sustainability of the resource for the coming generations.
- An extension campaign should be launched to encourage the local people to adopt trees at their farms and increase their stocking density.
- Organization of local communities into associations would enhance trading in the NWFPs; therefore raise the standard of living of local communities

References

Administration of Planning & Economic (1991) State investment guide.

Administration of Planning & Information (2006). Biannual report.

Albbas, A. A. (2006) Contribution of Non -timber Forest Products (NTFPs) in Household Livelihood in the Rural Areas of Shiekan Province, North Kordofan State, Sudan. Ph.D. Thesis, University of Khartoum.

Arnold, J. (1995) Socio-economic Benefits and Issues in Non-wood Forest Froducts use. In the Report of the International Expert Consultation on Non-wood Forest Products, Yogyakarta, Indonesia, 17-27 January 1995, FAO, Rome.

Burchinal, L., (1986) Lecture Notes and Steps in conducting a Survey. Presented at the 2 and Annual Forestry Extension Workshop on the Methodologies and Techniques in Conducts Forestry Extension Program in Sudan.

CFAN (1992) Forestry issues; Non-wood Forest Products: CIDA Forestry Advisers Network.

FAO (1985) Mentoring and Evaluation of Participatory Forestry Projects.

FNC (2008) Forests National Corporation Annual Report – El Obied, Sudan.

Impressions from the Workshop

The German Ambassador visited and participated in the workshop opening at the University of Khartoum.

Workshop Opening at the University of Kordofan, El-Obeid

Campus tour at the Faculty of Forestry, University of Khartoum

Introduction to Al-Musawwarat es-Sufra by Prof. Gaffar Mirghani

Camel meat lunch at the Camel Market, El-Obeid

Gum Arabic at the NTFP market and auction place

Visit of the Jabe Eldair Reserve Park, a biosphere reserve south of El-Obeid

Lunch break between the presentations sessions at El-Obeid

Visit of the Conflict Resolution Office El-Rahad

Group picture after two weeks of joint workshop and excursions

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Internationales Klimanetzwerk trifft sich im Sudan

Studenten und Mitarbeiter der TU Dresden reisten vom 3. bis 15. März 2013 in den Sudan, um gemeinsam mit afrikanischen Partnern effektive Wege zur Klimawandelanpassung zu diskutieren und das vom BMBF geförderte Programm »Welcome to Africa« zu stärken. Insgesamt kamen 50 Teilnehmer aus sechs Ländern in Khartum und El-Obeid zusammen.

Zehn Studenten (Forstwissenschaften, Geografie, Lehramt) hatten die Chance, an der »Summer School on Climate Change Adaptation« teilzunehmen und mit Prof. Jürgen Pretzsch, Inhaber der Professur für Tropische Forstwirtschaft, in den Sudan zu reisen. Von großer Bedeutung war es für uns Studenten, sich mehr mit dem Kontinent Afrika auseinanderzusetzen und persönliche Eindrücke vor Ort zu sammeln. Denn nicht immer stimmt die europäische Sichtweise mit der lokalen Realität überein. Naomi Daur befragte hierzu für das UJ den Forststudenten Jan Ladewig:

UJ: Was hat dich dazu motiviert, an der »Summer School« im Sudan teilzunehmen?

Jan Ladewig: Die Studienreise bot mir die Möglichkeit, spätere Berufsfelder kennenzulernen und Anregungen für meine Bachelorarbeit zu erhalten. Nach 2,5 Jahren Arbeit in Kenia bin ich an den Herausforderungen einer interkulturellen Zusammenarbeit interessiert.

Wie hast du dich darauf vorbereitet?

Neben den obligatorischen Reisevorbereitungen wie Impfungen, bereiteten wir Studenten uns mit der Ausarbeitung eines Exkursionsführers vor. Auch wenn dies in den Prüfungszeitraum fiel, hat sich die Arbeit gelohnt, da ich so eher örtliche Gegebenheiten verstehen konnte.

Wie habt ihr euch als Studenten vor Ort beteiligt?

Wir hatten die Chance, Konzepte und geplante Abschlussarbeiten zu präsentieren und von afrikanischen Wissenschaftlern ein Feedback zu erhalten. Durch Eigeninitiative konnte ich persönliche Gespräche mit den Menschen vor Ort führen und bei Ausflügen mündliche Beiträge leisten.

Welche Erlebnisse waren für dich besonders beeindruckend?

Vorträge zu nachhaltiger Waldbewirtschaftung, Umweltleistungen und Landnutzungskonflikten sowie Exkursionen hierzu konnten mein Wissen vertiefen. Besonders interessant fand ich den Besuch der antiken Stätte Musawwarat, des Kamelmarkts und des Auktionsareals für Gummi Arabicum, sowie in ein Biosphärenreservat südlich von El-Obeid.

Welche neuen Erkenntnisse hast du aus der Zeit mitgenommen?

Im Sudan werden völlig andere Anpassungsstrategien bedient als ich erwartet hatte. Die Diskussion über regenerative Energien erscheint mir zweitrangig, solange Menschen aufgrund von Desertifikation Hunger leiden. Naturschutzaspekte lassen sich oft nur als Sekundärziele verwirklichen, nachdem vorrangig finanzielle Einkommensquellen geschaffen wurden.

Die Reise war für uns Studenten ein wichtiger Schritt in ein internationales Berufsleben. Eine bedeutende Erfahrung war der intensive direkte Austausch mit afrikanischen Wissenschaftlern und Personen vor Ort. So wurde unsere fachliche als auch interkulturelle Kompetenz stark gefördert.

Naomi Daur und Jan Ladewig (Studenten)

Dorfbewohner eines Biosphärenreservats im Süden des Sudan stellen sich den Fragen der deutschen und afrikanischen Wissenschaftler und Studenten. Foto: Daur/Ladewig

»Scientific Cooperation Network on Climate Change Adaptation«, – DAAD-Programm »Welcome to Africa«, Juli 2012 – Juli 2015
Förderung: Bundesministerium für Bildung und Forschung (BMBF)
Partnerländer: Äthiopien, Sudan, Tansania, Uganda, Südsudan (im Aufbau)
http://tu-dresden.de/forst/w2a

Article published in the campus-journal of the Dresden University of Technology about the Summer-School, written by two students that participated in the project excursion.

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Scientific Cooperation Network on Climate Change Adaptation in Eastern Africa

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