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Fobissie Blese KALAME

**Forest governance and climate change adaptation:
Case studies of four African countries**

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**Forest governance and climate change adaptation:
Case studies of four African countries**

Fobissie Blese KALAME

*Academic dissertation
for the Dr. Sc. (Agric. & For.) Degree*

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ABSTRACT

Africa is threatened by climate change. The adaptive capacity of local communities continues to be weakened by ineffective and inefficient livelihood strategies and inappropriate development interventions. One of the greatest challenges for climate change adaptation in Africa is related to the governance of natural resources used by vulnerable poor groups as assets for adaptation. Practical and good governance activities for adaptation in Africa is urgently and much needed to support adaptation actions, interventions and planning.

The adaptation role of forests has not been as prominent in the international discourse and actions as their mitigation role. This study therefore focused on the forest as one of the natural resources used for adaptation. The general objective of this research was to assess the extent to which cases of current forest governance practices in four African countries – Burkina Faso, The Democratic Republic of Congo (DRC), Ghana and Sudan – are supportive to the adaptation of vulnerable societies and ecosystems to impacts of climate change.

Qualitative and quantitative analyses from surveys, expert consultations and group discussions were used in analysing the case studies. The entire research was guided by three conceptual sets of thinking – forest governance, climate change vulnerability and ecosystem services. Data for the research were collected from selected ongoing forestry activities and programmes. The study mainly dealt with forest management policies and practices that can improve the adaptation of forest ecosystems (Study I) and the adaptive capacity through the management of forest resources by vulnerable farmers (Studies II, III, IV and V).

It was found that adaptation is not part of current forest policies, but, instead, policies contain elements of risk management practices, which are also relevant to the adaptation of forest ecosystems. These practices include, among others, the management of forest fires, forest genetic resources, non-timber resources and silvicultural practices.

Better livelihood opportunities emerged as the priority for the farmers. These vulnerable farmers had different forms of forest management. They have a wide range of experience and practical knowledge relevant to ensure and achieve livelihood improvement alongside sustainable management and good governance of natural resources. The contributions of traded non-timber forest products to climate change adaptation appear limited for local communities, based on their distribution among the stakeholders in the market chain.

Plantation (agro)forestry, if well implemented and managed by communities, has a high potential in reducing socio-ecological vulnerability by increasing the food production and restocking degraded forest lands. Integration of legal arrangements with continuous monitoring, evaluation and improvement may drive this activity to support short, medium and long term expectations related to adaptation processes.

The study concludes that effective forest governance initiatives led by vulnerable poor groups represent one practical way to improve the adaptive capacities of socio-ecological systems against the impacts of climate change in Africa.

Keywords: Adaptive capacity, adaptation, Africa, farmers, forest, governance, vulnerability

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PREFACE

Two reasons motivated me to undertake this study: The first deals with helping governments, decision makers, development interventions and vulnerable communities in Africa in identifying and improving ongoing natural resources utilization, management and policy activities that can potentially support adaptation to the impacts of climate change. The second is linked to the adaptation role of forests that has gained less attention in the international discourse and actions as compared to their mitigation role. This study helped me to achieve my goals of attempting to bridge the gap between theory and practice, science and policy, and rhetoric versus reality. My thanks go to the financial, material, technical and moral support of many colleagues, family members, institutions and local communities who made it possible.

I am deeply indebted to my three supervisors. Prof. Olavi Luukkanen gave me the opportunity to join VITRI both for my Master's and Doctoral studies. His excellent guidance, unfailing support and flexible academic approach are greatly appreciated. Similar gratitude also goes to Prof. Markku Kanninen for the valuable discussions we had especially on the methodological framework and the overall practical relevance during the writing process. Last but not the least of my supervisors is Dr Johnson Nkem, who provided excellent specific guidance in the writing of separate manuscripts. I am also thankful to the reviewers of this thesis, Prof. Olli Saastamoinen and Associate Prof. Muluaem Tigabu for their constructive comments. The multidisciplinary approach used in this study would not have been possible without the valuable contribution of many co-authors at different stages of the study, ranging from the introduction of the research idea, planning and organization of field trips, data collection and analysis, to the writing and revision of the manuscripts. I am sincerely indebted to all the co-authors: Dr. Monica Idinoba, Dr. Edinam Glover, Prof. Elnour Elsiddig, Dr. Robert Aidoo, Dr. Oluyede Ajayi, Olufunso Somorin, Abdon Awono and Dr. Ousseynou Ndoye.

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Thanks to my wonderful mother and brothers – Youmbi Kalame and Wanzi Nganje for their steadfast support. Last but not the least, very special thanks are due to my dearest wife Elsie Fobissie, my son Darren Fobissie and daughter Rianne Fobissie for their endless support, understanding and patience that gave me the motivation to complete this study.

Helsinki, March 2011
Fobissie Blese Kalame

LIST OF ORIGINAL PAPERS

This thesis is based on the following original articles:

- I. Kalame, F.B., Nkem, J., Idinoba, M., Kanninen, M. 2009. Matching national forest policies and management practices for climate change adaptation in Burkina Faso and Ghana. *Mitigation and Adaptation Strategies for Global Change* 14:135-151.
- II. Kalame, F.B., Luukkanen. O., Elsiddig. E.A., Glover, E.K. 2010. Tree knowledge and livelihood activities in a changing environment: Views from smallholder farmers in Kosti, Sudan. *Journal of Sustainable Forestry* 29:591-612.
- III. Kalame, F.B., Luukkanen. O., Kanninen, M. Making climate change adaptation interventions more responsive: Tree planting in dryland Sudan (Submitted).
- IV. Kalame, F.B., Aidoo, R, Nkem, J., Ajayie, O., Kanninen, M., Luukkanen, O., Idinoba, M. 2011. Modified Taungya System in Ghana: A win-win practice for forestry and adaptation to climate change? *Environmental Science & Policy* (Accepted) doi: 10.1016/j.envsci.2011.03.011.
- V. Nkem J.N., Kalame, F.B., Idinoba, M., Somorin O., Ndoye, O., Awono, A. 2010. Shaping forest safety nets with markets: Adaptation to climate change under changing roles of tropical forest in the Congo Basin. *Environmental Science & Policy* 13:498-508.

In studies I, III and IV, Fobissie Kalame introduced the research idea, organised the field arrangements, collected and analysed the data and prepared the manuscripts, which were revised with O. Luukkanen, M. Kanninen, J. Nkem, M. Idinoba and O. Ajayie. In Study IV, R. Aidoo partly assisted in data collection. In study II, F. Kalame and E. K. Glover introduced the research idea and contributed to the development, data management and analysis, writing and revision of the manuscript. Additional contributions to the development and revision of the manuscript were made by O. Luukkanen and E.A. Elsiddig. In study V, J. Nkem introduced the research idea while F. Kalame, M. Idinoba, O. Somorin, O. Ndoye, and A. Awono contributed in the development, writing and revision of the manuscript.

LIST OF MAIN ACRONYMS AND ABBREVIATIONS

AC	Adaptive Capacity
APF	Adaptation Policy Framework
AFOLU	Agriculture, Forestry and Other Land Uses
CBA	Community-Based Adaptation
CBFM	Community-Based Forest Management
CBNRM	Community-Based Natural Resource Management
CDM	Clean Development Mechanisms
DRC	Democratic Republic of Congo
EBA	Ecosystem-Based Adaptation
IPCC	Inter-governmental Panel on Climate Change
LDC	Least Developed Countries
MA	Millennium Ecosystem Assessment
MGDs	Millennium Development Goals
MTS	Modified Taungya System
NAPA	National Adaptation Programme of Action
NTFPs	Non-Timber Forest Products
REDD	Reduced Emissions from Deforestation and Forest Degradation
ODA	Official Development Assistance
SD	Sustainable Development
SSA	Sub-Saharan Africa
UNDP	United Nations Development Program
UNFCCC	United Nations Framework Convention on Climate Change

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1. Introduction

1.1. Climate change adaptation and sustainable development

The United Nations Framework Convention on Climate Change (UNFCCC) provides an international framework for coherent and co-ordinated intergovernmental efforts to address climate change challenges within the overall global context of sustainable development (SD). Although recognized since the first UNFCCC Conference of the Parties (COP 1) in 1995, it was not until the adoption of the Marrakesh Accords in 2001 that adaptation actions became prominent under the convention. According to the World Summit on Sustainable Development (UN 2002), climate change threatens sustainable development as it could worsen the situation of the poor and make it more difficult to meet the Millennium Development Goals (MDGs) (CSD 2005). Apart from being a threat, climate change through the implementation of diverse adaptation measures could also be seen as beneficial for (African) development.

The need to mainstream climate change into development plans, policies, programmes and activities is increasingly being recognized by many local and national governments, intergovernmental organizations in addition to bilateral and multilateral development agencies. Mainstreaming entails the more efficient use of financial and human resources rather than designing, implementing and managing climate policy separately from ongoing development activities (Klein et al. 2007). The World Summit on Sustainable Development (UN 2002) provided a strong impetus to this discourse by supporting links between climate policy and development. The consideration of climate change in development activities could add a long term sustainability component to official development assistance (ODA). However, development agencies and national governments challenged to practice a 'no-regrets' climate change interventions that should reduce rather than increase vulnerability to climate change (Heltberg et al. 2009). Vulnerability to climate change can be reduced by adaptation to the impacts of climate change and mitigation of green house gas emissions. It can also be reduced by development aimed at improving the living conditions and access to resources for those experiencing the impacts, as this will enhance adaptive capacity (Ayers and Huq 2009).

The link between adaptation and development is particularly relevant when seeking to enhance the capacity of people and communities to adapt to climate change. This adaptive capacity is often limited by a lack of resources, poor institutions and inadequate infrastructure, amongst other factors that are typically the focus of ODA (Smith et al. 2003). There are three dimensions by which adaptation to climate change is relevant to development activities (Klein 2001) First, the risk of climate change to the development activity and its deliverables including water supply, infrastructure, food security, human health, natural resources management and protection against natural hazards. Second, is the vulnerability of the community or ecosystem targeted for development activity to climate change. Third, the possible adverse effects of the development activity and its deliverables on the vulnerability of communities or ecosystems to climate change (maladaptation).

The links between climate change and development activities are apparent. Nonetheless, people are not only vulnerable to climate change but to a range of other stresses that depend on factors such as access to resources and other socio-environmental circumstances shaped by

political and economic processes (O'Brien et al. 2004). These stresses may include access to forest products, water and food, health, education and livelihood security, and constitute priorities of the MDGs which have become guiding principles for the ODA. This implies that the formation of future development priorities, strategies and projects should consciously aim at reducing vulnerability (Klein et al. 2007).

A recipient country's objectives and priorities are supposed to guide the selection of climate change or development interventions pursued by a donor agency. However, a development agency's awareness of climate change can be important in: (i) dialogues with the recipient country on priority interventions to be supported (Ulsrud and Eriksen 2007) and (ii) also ensuring that the careful design and implementation of measures are more targeted at particular threats especially in situations where conflict arises between poverty reduction and vulnerability reduction (Adger et al. 2003). For example, in Africa the Nairobi declaration by the African Ministers of Environment on the African Process for Combating Climate Change clearly states that 'support for Africa under future climate regime should be based on priorities determined by Africa, which include adaptation, capacity building, research, financing and technology transfer of knowledge, in particular indigenous knowledge' (World Bank 2009a).

1.2. What role for governance?

Governance is a multi-faceted concept that has different meanings in different contexts. Generally, Kaer (2004) defined it thus: 'governance refers to the setting, application and enforcement of rules that include norms and formal and informal code of behaviour' (Kjær 2004 p. 189). Governance is different from governments, and involves the interaction of public and private actors that are bound together in diverse networks to solve societal problems and create opportunities. 'It includes the formulation and application of principles guiding those interactions and care for institutions that enable them' (Kooiman and Bavinck 2005). Multi-level governance deals with the sharing of decision making competencies. It involves local, sub-national, national and even regional or global level actors. Nevertheless, most of the debate on governance has focused on the efficiency and effectiveness of institutional outputs and less on the procedural inputs (Kjær 2004).

Awareness on the governance of climate change adaptation issues is growing globally and particularly in the Africa policy milieu. The adaptive capacity of local communities continues to be weakened by ineffective and inefficient livelihood strategies and inappropriate development policies. Despite this one of the greatest challenges for climate change adaptation is related to policy development, institutional co-ordination and overall governance strategies and mechanisms (Yamin 2004, Brook et al. 2005).

Much attention at the global level focuses on the provision and governance of adaptation funds. For example, Oxfam International estimated that some 50 billion US dollars of adaptation fund is needed yearly whereas some parties under the UNFCCC are 'concerned about legitimate and transparent governance mechanism to control the entire financing chain' (Person et al. 2009). The present study does not focus on issues on adaptation finance. Another crucial area

of concern has been the formulation of a climate change policy or mainstreaming climate change objectives and programmes into sectoral and development plans and activities.

Although negotiations on adaptation finance is at the core of international discussions, many governmental and intergovernmental initiatives in Africa take place, using a top-down approach at different regional, sub regional and national policy levels. For instance, at the continental level the African Ministerial Conference on the Environment (AMCEN) together with the African Union's New Partnership for Africa's Development (NEPAD), are keen to address climate change and adaptation, and international environmental governance. At the sub-regional level, The Economic Community of West African States (ECOWAS) and the Common Market for East and Southern Africa (COMESA) have established climate change adaptation and mitigation frameworks and programmes. In contrast, many national governments have formulated and are currently implementing the National Adaptation Programme of Action in addition to their national communications to the UNFCCC.

Knowing well that the impacts of climate change are always local, relevant initiatives at the different policy levels need to be supported so that they transcend to the local level at which adaptation actions occur. Responsive local adaptation actions serve the bottom up approach and play a complementary role that feeds back into the top-down adaptation policy structure. As Pahl-Wostl (2009) stated: 'more complex and diverse governance regimes have a higher adaptive capacity' (sic). Furthermore, a balance between top-down and bottom-up approaches increases adaptive capacity and thus the sustainability of resource governance regimes that could lead to a moderately balanced power between states, markets and community actors. Therefore, the enhancement of the best local natural resource governance practices for climate change adaptation in Africa is very much needed to support adaptation decision making processes. Before this can be achieved we must first identify and evaluate current practices.

The young 'Community-based Adaptation (CBA)' initiative, which has been promoted by the International Institute for Environment and Development (IIED) since 2005, represents one of the few locally-based bottom-up adaptation approaches. Most of these initiatives are related to the management natural resources that by themselves poses significant governance challenges and connects the socio-ecological systems *per se*. Examples include successive cases of community-based forest or watershed management. The broader challenge remains as to how much diverse best practices can be identified, analysed and the lessons learned brought to the table to support adaptation decision making and implementation.

1.3. Forestry at the centre of climate change

Forests and forestry play an important role in the activities under the UNFCCC (Forner 2005). The climate change mitigation role of forests has been far more prominent in international discourse and actions than the adaptation role of forests. With climate change mitigation activities, forests have been defined differently. The definition depends on country-specific values from a range provided in the Marrakech Accords for the minimum area, crown cover and tree height. Generally in many African countries, forests are defined mainly in terms of legal classification of land area that has or previously had trees or forest. In some cases communities classify particular areas under their management as forest irrespective of the type

and level of vegetation. This is quite evident in arid countries that have fewer forests and less tree resources than communities living in wetter climates. Global Forest Resources Assessment (FRA 2010) defines forest as an area with tree crown cover of more than 10 per cent of the ground and area of more than 0.5 hectares with trees higher than 5 meters.

Many scholars and institutions have worked extensively on the mitigation potentials of forest with much focus on the 'clean development mechanisms (CDM)' and 'reducing emissions from deforestation and forest degradation (REDD)'. The UNFCCC also focused on afforestation, reforestation, deforestation and forest management under the development of rules of the Kyoto Protocol (Forner 2005). One major development under UNFCCC was the publication of guidelines for reporting greenhouse gas emissions by sources and removals by sinks resulting from land use, land-use change and forestry (LULUCF). Many methodological and governance challenges still remain however (Angelsen 2008, Miles and Kapos 2008, Cotula and Mayers 2009). An overall framework, 'agriculture, forestry and other land uses (AFOLU),' is also being proposed at the UNFCCC as another credible mitigation activity across landscape (Trines et al. 2006). The high focus on forestry mitigation potentials can be explained by the fact that, about a fifth of global green house gas (GHG) mainly coming from tropical deforestation and other land use sources (Stern 2006). Forestry activities such as afforestation and reforestation can also contribute in the sequestration of CO₂. Forests offer one of the cheapest, most efficient and immediate solutions to the World's rapidly rising carbon emissions. If unchecked, the cost of climate change caused by deforestation could reach 1 trillion US \$ annually by the year 2100, whereas the net benefit of halving deforestation could total 3.7 trillion US\$ over the long term (Eliasch 2008). Addressing tropical deforestation is part of the solution but is such a complex and diverse issue. Most of the underlying drivers often originate outside the forest sector. For example, in the Congo Basin mining operations, charcoal production, and international markets for agricultural and forest products drive deforestation. Another issue is forest degradation that is common in arid Africa especially in the Sahel region.

Hitherto forests and adaptation has not been a very prominent subject for scholars or the UNFCCC or the recent Intergovernmental Panel on Climate Change report (IPCC 2007). Some developing countries have been engaged in the elaboration and implementation of national communications and National Adaptation Programmes of Actions (NAPA). In contrast, the role of forest for adaptation is scantily mentioned in some national communications. In Mali, forests are considered as a service provider to other vulnerable sectors such as water, agriculture and livestock. In Ghana, forests are mainly considered as a source and sink for carbon with less focus on its adaptation role. On the other hand, Burkina Faso proposed adaptation strategies and options in the forest sector. These measures focus more on reinforcing the protection of forest resources. On the NAPA side, countries such as Sudan, Burkina Faso, Mauritania, Niger, Senegal and Gambia have proposed tree planting and forest protection and conservation as adaptation actions to reduce the vulnerability of their societies and environments to the impacts of climatic change. These activities are usually implemented through agroforestry, rehabilitation/reforestation of degraded lands, stabilization of sand dune movement and the protection and restoration of watersheds.

The work of Seppala et al. (2009) presents one of the few global views on forest and climate change adaptation options. Forests and forestry provide diverse resources, which are drawn upon by the respective society for earning livelihoods and adaptation actions. Most of these resources go beyond the protective functions of forest, notably the use of diverse NTFPs as 'safety nets'. Livelihoods in Sub-Saharan Africa (SSA) are so dependent on forest and other natural resources, and climate change adaptation is such a huge priority both at the political and livelihood levels. Neither the impacts and institutional response of climate change with regard to forests, nor the role forests play in a society's adaptation are well understood by many decision makers and development actors: especially in the context of the SSA. Therefore, more research may improve the understanding of these issues. Moreover, the proposed activities under NAPA and national communications are not new, though the climate change concept might be. In this light, the proposed activities discussed in this thesis merit critical attention because wrongly focused and poorly conducted interventions can actually increase vulnerability. Alternatively, they might have no positive effect in improving the capacity of the vulnerable poor to adapt to the impacts of climate change.

1.4. Aims of the study

The general objective of this study was to assess the extent to which current forest governance practices in Africa are supportive of adaptation of vulnerable societies and ecosystems to the impacts of climate change. The study was based on selected forestry activities in four African countries - Burkina Faso, the Democratic Republic of Congo (DRC), Ghana, and Sudan.

The specific objectives of this study were to:

- (1) Identify current forestry policies and management interventions that can help forest ecosystems adapt to climate risks (Study I- Burkina Faso and Ghana).
- (2) Examine the utilization and management of trees by smallholder farmers for livelihood improvement and environmental protection (Study II- Sudan).
- (3) Analyse farmers' experiences in tree planting in gum agroforestry as a proxy to guiding the design and implementation of tree related adaptation projects (Study III- Sudan).
- (4) Assess the compatibility of plantation (agro) forestry with features of a climate change adaptation strategy (Study IV- Ghana).
- (5) Evaluate the role of markets on non-timber forest products (NTFPs) and the implications for climate change adaptation (Study V- Democratic Republic of Congo).

Hypotheses

The research was based on the hypothesis that the identification of (best) forestry practices, which enhances livelihood and ecosystem resilience and strengthens forest governance, is a practical option and provides a mechanism for governments to address and adapt to climate change risks.

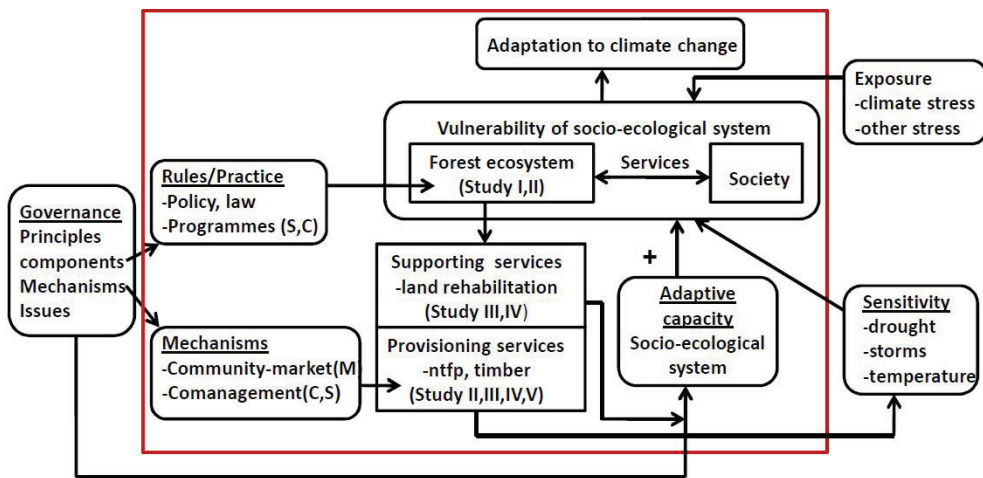
Individual studies within the research were based on the following specific hypotheses that:

- (1) Current forestry practices determine the nature and extent of management intervention required to address climate risks (Study I).
- (2) Integrated agriculture and tree management practices may lead to sustainable land production systems (Study II).
- (3) Climate change (adaptation) projects that build on lessons, experiences or perceptions from past activities are likely to be more responsive (Study III).
- (4) Modified Taungya System of Ghana is a potential adaptation strategy to reduce vulnerability to climate risks (Study IV).
- (5) The level of contributions of NTFPs to climate change adaptation depends on the governance of actors in the market chain (Study V and III).

2. Theoretical Framework

2.1. Analytic frame

The theoretical framework of the present study draws on three conceptual areas in the literature. The first is the climate change vulnerability and adaptation concept. The second is the forest/environmental governance literature. The third area builds on literature regarding the livelihood dependence on ecosystem services. The first and second bodies of literature of the study are complementary. Moreover, they both build around and focus on the issues in the third body of literature.



The + sign means that high adaptive capacity reduces vulnerability and enhances adaptation. Influential governance actors: S-state, C-community, M-market actors.

Figure 1. General framework of the study. This study focuses on issues within the box.

A major part of the present study focuses on how some aspects of governance mechanisms can influence the adaptive capacity of vulnerable forest-dependent farmers and communities. NTFPs are key resources for communities' adaptations to climate change impacts. Another part of the present study focuses on policy programmes and activities that can shape the adaptation and vulnerability of forest ecosystems to climate change. However, the present study does not cover other important aspects of forest governance, which *inter alia* cover: decentralization, forest tenure and property rights and corruption. Besides being 'important', some of these issues are more than 'fundamental prerequisites' for sustainable and just governance and governmental activities. The discussion, and conclusion and recommendation chapters of this study bring much of this type of consideration into the forefront. The study

also focuses to a lesser extent on the exposure and sensitivity components of vulnerability. The general framework of the study is presented in Figure 1. The four study areas farming communities primarily depend on rain-fed land and constitute one of the groups most vulnerable to and disproportionately affected by climate change impacts in Africa. Their views in many climate change activities or interventions in many developing countries are marginalized (UNFCCC 2009).

2.2. Vulnerability and adaptation to climate change

Many studies emphasize and recommend the need to look at increasing adaptation and reducing vulnerability to climate change through a holistic or integrated approach. Such an approach explicitly promotes multiple objectives linked to: vulnerability reduction, poverty reduction, sustainable natural resources management, environmental protection, conflict resolution and strengthening livelihood strategies (Adger et al. 2003, Sperling 2003, Lim et al. 2005, MA 2005, Nyong and Fiki 2005, Brooks et al. 2005).

2.2.1. The concept of vulnerability

The Intergovernmental Panel on Climate Change (IPCC) defines vulnerability (V) as ‘the degree to which a system is susceptible to, or unable to cope with the adverse effects of climate change, including climate variability and extremes’. ‘Vulnerability is a function of the character, magnitude and rate of climate variation to which a system is exposed (E), its sensitivity (S), and its adaptive capacity (AC)’ (McCarthy et al. 2001, p.995). Mathematically, V is a function of E, S and AC i.e. $V = f \{E, S, AC\}$. A high E, high S and low AC induce high vulnerability whereas high AC induces low vulnerability (McCarthy et al. 2001).

This same report defined exposure as ‘the nature and degree to which a system is exposed to significant climatic variations’. In this definition, exposure refers to biophysical or climatic exposure (Brooks 2003, Locatelli et al. 2008). However, ‘exposure’ can be modified to include socioeconomic exposure (O’Brien et al. 2004) that will in turn address biophysical and social vulnerability. Sensitivity is ‘the degree to which a system is affected, either adversely or beneficially by climate-related stimuli’. For example, a change in crop yield due to drought or frequent flooding due to changes in rainfall frequency and intensity is a measure of how sensitive the system is.

2.2.2. Characteristics of adaptive capacity

Adaptive capacity is ‘the ability of a system to adjust to climate variability and change to moderate potential damages, to take advantage of opportunities, or to cope with the consequences’ (McCarthy et al. 2001). Adaptive capacity was also defined by Smith and Pilifosova (2001) as ‘the potential or ability of a system, region or community to adapt to the effects or impacts of climate change’ (sic). Adaptive capacities have different characteristics and vary across households, communities, nations and regions. In the case of communities, an

adaptive capacity is determined by the socioeconomic characteristics of the communities and their ability in responding effectively. Countries/communities with limited economic resources, low level of technology, poor information and skills, poor infrastructure, unstable or weak institutions, and inequitable empowerment and access to resources have little capacity to adapt and are highly vulnerable (McCarthy et al. 2001). Yohe and Tol (2002) defined the determinants of adaptive capacity as 'the range of available technological options for adaptation, availability of resources and their distribution across the population, institutional structures and decision making authorities, human and social capital including education, personal security and property rights, systems' access to risk spreading processes, information needs, perceptions and decision making credibility' (sic).

Similarly, IPCC (McCarthy et al. 2001) presented key determinants of adaptive capacity (AC) which can be summarised into:

- Economic resources: more economic resources increase AC, whereas the lack of financial resources limits adaptation options.
- Technology: where the lack of technology limits potential adaptation options.
- Information and skills: lack of information and trained personnel reduces AC. Greater access to information increases likelihood of timely and appropriate adaptations.
- Infrastructure: greater infrastructure can enhance AC, whereas the location and characteristic affect AC.
- Institutions: policies and regulations constrain or enhance AC. Well developed social institutions help to reduce impacts of climate risks and increases AC.
- Equity: equitable distribution of resources increases AC. Both the availability of and the entitlement to resources affect AC.

According to O'Brien et al. (2004) adaptive capacity approach leads to the emergence of policy measures that focus less on technical aspects and more on social aspects, including poverty reduction, diversification of livelihoods, protection of common property resources such as community forest, and strengthening of collective action. Hence the enhancement of adaptive capacity is necessary to reduce a system's vulnerability to hazards and promotes sustainable development (Rayner and Malone 1998, Munasinghe 2000, Smith et al. 2000).

2.2.3. Vulnerability assessment of coupled socio-ecological systems

In addition to the definition of vulnerability by IPCC, other scholars Turner et al. (2003) and Metzger et al. (2005) defined and assessed vulnerability with a particular emphasis on coupling the human and natural systems as they interact. Different terminologies and concepts have been used by scholars that range from human-environment system, ecosocial systems, and socioecological systems to socio-ecological systems. All of which illustrate the interaction between human and ecological systems that have only artificial boundaries (Turner et al. 2003, Folke et al. 2005). These interactions result in reciprocal feedbacks and represent complex adaptive systems that cannot fully be analyzed either as a social or ecological system alone (Folke et al. 2005).

Locatelli et al. (2008) was prompted by the works of Turner et al. (2003) and Metzger et al. (2005) to define three principles that consider the role of ecosystem services for society to assess vulnerability and plan for the adaptation of socio-ecological systems. First, the vulnerability of ecosystem services to climate and non-climate threats. Second, the vulnerability of the society due to the loss of ecosystem services they depend on. Third, the adaptive capacity of the socio-ecological system as a whole.

2.2.4. Responsive adaptation

The Intergovernmental Panel on Climate Change (McCarthy et al. 2001) defines adaptation as ‘an adjustment in natural or human systems to actual or expected climate risk or their effects, which moderates harm or exploits beneficial opportunities’. Wrongly focused and poorly conducted interventions can actually increase vulnerability (McGuire and Sperling 2008) or have no positive effect in improving the capacity of the vulnerable poor to adapt to impacts of climate change. On the other hand, a responsive adaptation processes should assist socio-ecological systems to adapt to the impacts of climate change. Responsive adaptation processes (activities, interventions or adjustments) can be categorized into three broad aspects: processes that aim at creating or enhancing (i) resilient and improved livelihood outcomes, (ii) resilient and productive ecosystem conditions and (iii) supportive governance conditions (EPA 2004, Plummer and Armitage 2007). Nelson et al. (2007) argue that a resilient approach for adaptation is preferable. This is because it is system oriented, more dynamic and considers adaptive capacity (AC) as a core feature of resilient socio-ecological systems (SES). These in turn are used to analyze the adaptation processes and identify appropriate policy responses. According to Gallopin (2006) ‘the resilience, AC and vulnerability of SES are associated in non-trivial ways that are unclear’. For instance, some authors equate AC to resilience (Smith and Wandel 2006) and use AC as a component of resilience in responding to disturbances (Carpenter et al. 2001). In contrast, some define AC as a system’s robustness to change in resilience (Gunderson 2000). However, it is clear that a resilient system has a better AC and is less vulnerable than a non-resilient one (Gallopin 2006).

The first category of adaptation process centred on vulnerable poor people is likely to have an impact in reduction of poverty and improving their capacity to respond to climatic and non climatic stresses. Such potential impacts on vulnerable poor groups could be realized through improved economic opportunities for vulnerable poor groups, provision of water supply, education and health, diversity of food source and livelihood activities, processing and marketing of local products, subsistence utilization of natural resources etc. (Eriksen and Naess 2003).

The second category of adaptation projects centred on the vulnerable environment or ecosystems. These projects are most likely to improve the resilience and provision of ecosystem goods and services. Potential activities could involve but not be limited to risk planning: in natural resource management, early warning systems, co-management and climate impact defences systems against flood, storms, drought and desertification, etc.

The third category is centred on promoting good governance: it is likely to support livelihood improvement and environmental management. This aim should be met through the following mechanisms: increased and improved access to ownership and viability of communal resources, extension services, decentralized management of natural resources, policies that enhance marketing and profits of local products for vulnerable groups, linkage between local informal and formal institutions and integration of local knowledge and climate change into development activities (Eriksen and Naess 2003).

The criteria for assessing the success of adaptation activities or projects: are context specific, varies from project to project, and from place to place. These criteria can also be constrained by the spatial and temporal scales of analysis. The criteria include elements of the following: project effectiveness and efficiency, equity and institutional flexible (Adger et al. 2005, Hedger et al. 2008). According to Adger et al. (2005), an effective adaptation project is required to reduce both short and long term vulnerabilities without producing negative unintended impacts to the adapting agent. The economic efficiency of an adaptation project is determined by the relationship of the cost and benefits (market and non-market value) and the timing of the project in relation to the climate change impact, whereas equity issues relate to the distribution of benefits and costs among people and stakeholders of adaptation projects. Studies by Adger et al. (2003) and Thomas and Twyman (2005) pointed out that 'present-day adaptation interventions reinforce existing inequalities and do little to alleviate underlying vulnerabilities'. Furthermore, institutional flexibility takes into account future uncertainties and also learns from experience and incorporate lessons into climate change interventions to facilitate successful adaptation.

2.2.5. Adaptation approaches and frameworks

Three main approaches of adaptation are common. The first approach is planned adaptation, which is supported by deliberate climate forecast, undertaken by local, government and the private sector. Planned adaptation commonly focuses on developed countries (Yohe and Tol 2002). The second, is autonomous adaptation, which is characterized by the ability of vulnerable individuals, households, communities to adapt to impacts of climate change (Smith et al. 2000). The third approach is the development of adaptive capacity to help individuals, communities and organizations effectively to respond and adapt to climate change. The development of adaptive capacity mainly focuses on developing countries (Lim et al. 2005). In ecological systems adaptation is reactive i.e. in response to initial climate impacts. On the other hand, in social systems it can be both anticipatory i.e. response before impacts takes place and reactive (Smith et al. 2000). Adaptation process can be implemented by individuals, households, communities, commercial companies and non-governmental organizations, whereas public actors include government bodies at all levels (Klein 2001). Many frameworks exist to help governments, development interventions and vulnerable communities. This is particularly important for the developing countries to plan and implement responsive adaptation processes and policies. Such frameworks include; National Adaptation Programme of Action (NAPA), Adaptation Policy Framework (APF) and Ecosystem-Based Adaptation Approach (EBA).

NAPA: At the level of the UNFCCC all of the Least Developed Countries (LDCs), face the most severe levels of poverty and are deemed highly disadvantaged in their development process, are expected to formulate and submit a NAPA document. NAPA requires LDCs to formulate national and regional programmes to facilitate measures for adequate adaptation to climate change. Through the NAPA process, LDCs can identify existing coping mechanisms, prioritise future adaptation activities that require support and enhancement and identify areas that need more investment and have the potential to strengthen the countries' adaptive capacities (Brown and Crawford 2008).

APF: APF is a flexible framework that has been developed by the United Nations Development Programme (UNDP). Its purpose is to assist national, regional and local level interventions develop and implement adaptation strategies and processes in the context of sustainable development against the rapidly evolving process of adaptation policy-making (Lim et al. 2005). APF provide the opportunities for communities and governments to actively participate, address their priorities and implement responsive adaptation strategies, policies and measures that enhance the adaptive capacities of socio-ecological systems to cope better with climate change.

EBA: EBA refers to the use of ecosystem goods and services for planning adaptation or to carry out adaptation already planned by multiple actors by using multi-sectoral and multi-scale approaches (World Bank 2009b). EBA complements other climate change responses or substitutes in the place of more expensive measures by providing, restoring and maintaining goods and services needed for adaptation, and by providing cost-effective climate responses (World Bank 2009b). EBA is intended to manage human activities in ecosystems (Bunch et al. 2008) and essential ecological processes while safeguarding their integrity and resilience (Elmqvist et al. 2003).

2.3. Forest ecosystem services and livelihoods

2.3.1. Ecosystem services

The concept of ecosystem services is commonly used nowadays for linking the functioning of ecosystems to human well-being (Fischer et al. 2009). Several definitions for ecosystem have been cited. Daily (1997) defines ecosystem services as the conditions and processes through which natural ecosystems and their constituent species sustain and fulfill human life. Constanza et al. (1997) defines ecosystem services as the benefits human populations derive, directly or indirectly, from ecosystem functions. On the other hand, the Millennium Ecosystem Assessment-MA (MA 2005) defines ecosystem services as the benefits people obtain from ecosystems. Unlike MA, Boyd and Banzhaf (2007) defines ecosystem service as the ecological components/ products directly consumed or enjoyed to contribute to human well-being.

Some scholars (Fischer et al. 2009) argue that any attempt at classifying ecosystem services should be a function of both ecosystem and ecosystem service characteristics. The decision-making context for this is influenced by the following: benefits from rival and excludable goods, spatial and temporal dynamism of ecosystems and their services, multiple services

produced by an multiple ecosystems, ecosystem complexity structure, process and service, and benefits dependent upon understanding of ecosystem services. However, Fischer et al. (2009) uses the definition of MA, which classifies ecosystem services into supporting, provisioning, regulating and cultural services.

According to the Millennium Ecosystem Assessment-MA (MA 2005), supporting services are services needed for the production of all other ecosystem services, which *inter alia* include soil formation, nutrient cycle and primary production. Provisioning services are those goods produced by ecosystems such as timber, fiber, fuelwood, food, medicinal plants etc. Regulating services are benefits obtained from the regulation of ecosystem processes such as climate regulation, detoxification, flood control, disease and desertification etc. Cultural services are non-material benefits provided by ecosystems that include spiritual, educational recreational, aesthetic, symbolic etc.

Current understanding of the relationships and mechanisms between most ecosystem process and most services remain weak (Carpenter et al. 2009). This limits our knowledge on when and how to minimize trade-offs and enhance synergies among ecosystem services (Bennett et al. 2009). This limitation has also driven humanity to focus on the most desired ecosystem services that have led to an increase in a few goods and services such as food, timber and fiber and a decrease in other services such as flood control, combating desertification, genetic resources and pollination (MA 2005). In a review, Bennett et al. (2009) presented three hypotheses to achieve improved management of relationships among multiple ecosystem services. First, an integrated socio-ecological approach might provide a better assessment or identification of relationships. Second, understanding the mechanisms that influence responses of multiple services to a specific driver may help identify points of management intervention that can yield maximum benefits. Third, managing the relationship among ecosystem services can enhance ecosystem resilience and continuous provision of services, and prevent a sudden shift in the provision of ecosystem services.

2.3.2. Dependence of livelihood on forest ecosystem services

Many rural households in developing countries and Africa in particular are predominantly engaged in diverse livelihood strategies and activities. One of these strategies is the extraction of forest products and it provides a substantial contribution to their well-being (Babulo et al. 2009). Other livelihood strategies include crop cultivation, livestock husbandry, unskilled jobs and trading. A livelihood is defined as comprising ‘the capabilities, assets and activities required for a means of living. A livelihood is considered to be sustainable when it can cope with and recover from stress and shocks and maintain or enhance its capabilities and assets both now and in the future (sic)’ (Chambers and Conway 1992).

Many scholars have used the sustainable livelihood approach (SLA) as a framework for establishing the role of forest products as safety nets for rural livelihoods using the different assets that forest provide (Warner 2000, Kaimowitz 2003, Nhantumbo et al. 2003, Gundimeda 2004, Kaushal et al. 2004, Grieg-Gran et al. 2005). Under the SLA, livelihood assets include natural (e.g. forest, soil), social (e.g. social groups), financial (e.g. credits, savings), physical

(e.g. farm tools) and human (e.g. skills, education). Access to these assets determine the choice of a livelihood strategy in addition to livelihood outcomes that mainly include but are not restricted to increased income, food security, reduced vulnerability, sustainable natural resources management (Carney 1998).

Forest income: In recent years the importance of NTFPs commercialisation as a means to reduce poverty and conserve forests has become prominent (Brown and Lassoie 2010) as the dependence of poor rural livelihoods on forest income increases (Campbell et al. 2002). A meta-analysis of 51 case studies from 17 developing countries, conducted by Vedeld et al. (2007), revealed that the income from forest products especially fuel wood, wild food and fodder represented a mean of 22% of the total income in the population sampled. Similarly, Babulo et al. (2009), after sampling 360 rural households in 12 villages in northern Ethiopia, found that income from forest products occupied the second largest share of the mean total household income after crop income. Many governments in Africa also value timber production for income generation more than any other forest ecosystem services, whereas livelihoods in many rural communities in Africa depend to a greater extent on NTFPs for subsistence and income generation (Vedeld et al. 2007, Babulo et al. 2009). This is similar with the global trend for which the highest proportion (30%) of the functions of the world's forests is designated for production of timber and also NTFPs (FRA 2010).

Food security and NTFPs: Food security is determined by food availability, access, utilization and the stability of food supply (FAO 2003a). Forest products especially NTFPs contribute to food security either through direct family consumption or by indirect means such as the selling of NTFPs to buy other household food items (Clendon 2001). In many parts of Africa, food security is supported by animal and plant products. The animal food products range from honey, bush meat, fish shells, edible bird eggs and insects whereas plant food products include stems, shoots, tubers, roots, leaves, flowers, fruits, nuts, oil seeds, condiments, spices and edible fungi. The majority of the population in Sub-Saharan Africa with as much as 90% in Ethiopia, Tanzania and Democratic Republic of Congo rely on wood fuel energy to cook food (Woodfuel and energy consumption 2006). Many households also engage in the extraction and commercialization of other forest products such as wood fuel, gum, resin and timber to generate income used in purchasing food. Management challenges as to the sustainability of ecosystems and the continuous supply of NTFPs still remain however (Brashares et al. 2004).

2.3.3. Forest ecosystem services and response to climate change

Tropical forests are important in addressing global climate change (Lewis et al. 2009). At the global level, forest ecosystems could play a significant role in atmospheric carbon sequestration (Angelsen 2008). On the other hand, vulnerable poor communities depend on forest goods and services to adapt to impacts of climate change at the national and local levels (Locatelli et al. 2008), which the present study addresses.

Tropical forests are considered as safety nets as they provide several goods and services to help people survive in times of crisis. These crises include drought or flood-induced crop failures, poor health, energy shortage etc. (Nkem et al. 2008). This safety net role represents a

crucial mechanism and reactive measure for climate change adaptation in natural resource-dependent communities (Nkem et al. 2008). Stern (2006) classifies forest safety nets for livelihood and national development into three functions: insurance, gap filling and alternative livelihood activities. All these functions represent major adaptation assets in responding to climate change (see Table 1).

Table 1. Forests safety net mechanisms as household livelihood coping strategies

Coping with adversities	Function	Description
Safety net	Insurance	Food and cash income in periods of unexpected food and income shortfalls
Support current consumption	Gap-filling	Regular and irregular food and income shortfall, such as crop failures and seasonal shortages
Occupational activities	Source of employment and for diversification	Unexpected job loss, off-cropping season activities such as firewood exploitation, artisan handicrafts

Source: Modified by Nkem et al. (2008) from Stern (2006)

2.4. Forest and environmental governance

More recently, Biermann et al. (2009, p. 3) defined governance in the context of an earth systems perspective as, ‘. . . the interrelated and increasingly integrated system of formal and informal rules, rule-making systems, and actor-networks at all levels of human society (from local to global) that are set up to steer societies towards preventing, mitigating, and adapting to global and local environmental change’(sic). Similarly, ‘environmental governance refers to the set of regulatory processes, mechanisms, and organizations through which political actors influence environmental actions and outcomes’ (Lemon and Agrawal 2006). Good governance is increasingly gaining importance with respect to forests and environment especially under the different UNFCCC, biodiversity (UNCBD) and desertification (UNCCD). The United Nations Development Programme (UNDP) developed/described five principles of good governance. First, legitimacy and voice based on participation and consensus orientation. Second, direction based on strategic vision. Third, performance based on responsiveness. Fourth effectiveness and efficiency, accountability, transparency, and fairness based on equity and the rule of law (UNDP 1999). According to Mayers et al. (2006), ‘Many aspects of governance impact forests but only some of them could be said to be forest governance’.

2.4.1. Components of forest governance

Many organizations are working towards a better understanding of governance of forest in different contexts and in different countries in order to provide baselines for monitoring progress in improving forest governance. In some cases the forest governance directly targets forest governance within the context of climate change adaptation or mitigation issues. These

include but are not limited to organizations such as the World Bank, the Centre for International Forestry Research (CIFOR), the International Tropical Timber Organization (ITTO), the United Nations (UN-REDD), the World Resources Institute (WRI), Chatham House, and the International Institute of Environment and Development (IIED). For example, the World Bank (2009c) generated a much detail tentative list of five building blocks of forest governance, their principal components and indicative subcomponents (see Table 2) whereas the ‘Governance of Forest Initiative (GFI)’ has developed a preliminary toolkit version to assess forest governance across countries (WRI et al. 2009). Unlike the World Bank, GFI uses three major forest governance components: actors, rules and practices, which are somehow relevant to one of the specific cases covered in this study.

Table 2. The building blocks of forest governance and their components

Building Block (Governance principles)	Indicative governance components
Transparency, accountability and public participation	Transparency in the forest sector Decentralization, devolution and actors in forest management Accountability within forest agencies and to stakeholders
Stability of forest institutions and conflict management	Stability of forest institutions to different management risks Management of conflicts over forest resources
Quality of forest administration	Willingness to address forest-sector issues Capacity and effectiveness of forest agencies Corruption control within the forest sector Forest monitoring and evaluation
Coherence of forest legislation and rule of law	Quality of domestic forest legislation Quality of civil law implementation Quality of criminal forest law implementation Quality to forest adjudication Property rights recognized, honoured and enforced
Economic efficiency, equity and incentives	Maintenance of ecosystem integrity Incentives for sustainable forest use Forest products pricing Commercial timber and non-timber forest products trade Equitable forest tenure, access and benefits Market institutions, forest revenues and expenditures

Source: Modified by the author from World Bank (2009c)

Actors are representatives of different institutions involved in decision-making from the local to the national level. These institutions may range from government, traditional, civil society, local communities, academic, international organizations to the business communities. According to North (1990), institutions provide the ‘rules of the game in society’. By providing a source of control, incentive, or disincentive, they affect how authority is

constituted, exercised, controlled, and redistributed (Ostrom 2007). By giving the chance to selected voices to be heard institutions may recognize certain actors and exclude others. Alternatively, by defining the validity of opinion, institutions can set criteria for the effective selection of claims (March and Olson 2004). Hence, institutional outcomes are the products of political bargaining and conflict between rulers and other societal institutions and groups (North 1990, Knight 1992).

According to GFI (WRI et al. 2009) rules refer to the content, context, scope of policies and laws, and also the process of designing and updating them. In regularizing the rules, institutions aim at stabilizing the activities and interaction of agents and help avoid conflict (March and Olsen 1989).

Practices refer to the operational level and outcome of the interaction between actors and rules (WRI et al. 2009). Practices take the form of programmes and projects implementation, management, monitoring, enforcement and adjustment. The spatial and temporal scope of programmes and projects is highly influenced by the availability of different resources (financial, social, political, human, physical and natural).

2.4.2. Mechanisms of forest and environmental governance

Some of the most important emerging trends in environmental governance include: globalization, decentralization, market forces, individual focused instruments, and governance across scale; are now giving way to emerging hybrid modes of governance across the state-market-community division (Lemon and Agrawal 2006). With the current and predicted impacts of climate change coupled with the increasing and competing demands for environmental services, food and energy, good governance of forests is becoming even more challenging (Agrawal et al. 2008). In a review of governance approaches to solve environmental problems and conflicts, Lemon and Agrawal (2006) identified three main mechanisms: co-management, public-private partnerships, and private-social partnerships.

Co-management is a hybrid form of collaboration, in the management of natural resources, between state agencies and communities. There is an agreement on power sharing by which communities function as either a co-manager or designated manager with clear benefits and responsibilities (Luukkanen et al. 2006). Strategies under this approach include community-based forest management (CBFM) or community forestry that may involve rehabilitation of degraded land, tree planting or conservation of forest resources (Kalame 2006).

Public-private partnership is a hybrid form of collaboration between the state agencies and market actors. Market actors refer to either individuals or companies. This partnership may take the form of contracting out of services, business management of state property, risk-sharing and co-production between state and market actors (Skelcher 2005). Under this mechanism, strategies such as logging and concessionary contracts are required to satisfy certain goals and in most cases do not genuinely favour a pro-poor agenda such as in the Congo Basin countries (Karsenty 2008). Such goals can be technical, economic, social, fiscal and environmental factors.

Private-social partnership represents a hybrid form of collaboration between communities and the market actors. Communities provide forest goods and services for sale to the market actors. This form of partnership is increasingly gaining ground with new and promising conservation instruments such as payments for environmental services (PES). According to Wunder (2005) 'PES schemes are ready to pay, if or when the service is actually delivered. It can benefit buyers (i.e. market actors), sellers (i.e. communities) and improve the resources base especially in marginal lands with moderate conservation opportunity costs'. However, PES has poverty reduction as an important aim but never as the primary objective. Wunder (2005) classified four main PES schemes, these include: carbon sequestration and storage, biodiversity protection, watershed protection and ecotourism.

3. Materials and Methods

Qualitative and quantitative research methodologies were used in this study. Qualitative methodology allows the researcher to have an open mind (the design emerges as the study unfolds), it also provides an opportunity to collect empirical research data by various methods and change or modify the approach if necessary (Bryman 1988). Quantitative methodology was also used in this study to complement qualitative data especially in situations for which the researcher needed precise measurement or to classify features, count them, and construct statistical models in an attempt to explain what was observed. In this regard, tools such as (semi-) structured questionnaire were used for data collection.

A top-down and bottom-up analysis was undertaken to understand the respective views at macro and micro levels of governance interplay (Sabatier 1986, Hill and Hupe 2002). The quantitative data was analyzed using descriptive statistics. Analytical techniques used for qualitative data in this study included “discourse analysis and content analysis”. Discourse and content analyses in this study draw upon the analysis of conversations (Tischer et al. 2000) and written text (Fairclough 2003) in the context of the views expressed (Bryman 1988, Krippendorff 2004).

3.1. Study countries and data set

The present study was conducted in four African countries: Burkina Faso (BF), the Democratic Republic of Congo (DRC), Ghana and Sudan (Fig 2). The climatic and non-climatic data related to vulnerability in the different studies (I-V) were fairly homogenous. The focus groups were forest managers and vulnerable poor smallholder farmers (Table 3). Data for the different studies were collected from selected vibrant forestry activities and programmes (or “best practices”) (Table 4) from these countries. The existing climate gradient of these countries run from the Sahara desert (Sudan) through the Sahel (Sudan and Burkina Faso), and down to coastal Ghana and the Congo Basin forest (DRC).

3.2. Methods

Study I: Policy and management interventions that help forest ecosystems adapt to climate risks

A comparative forest policy analysis between Burkina Faso and Ghana was carried out using policy content analysis, document review and expert consultations. Selected forestry practices in these countries were identified in relation to a set of proposed adaptation measures for forests, which were gathered from various studies. The strength and gaps of existing policy statements and measures such as laws, legislations, programmes and projects relevant for the adaptation of forests to impacts of climate change were analyzed in order to understand the nature and extent of the intervention needed.

Study II: Utilization and management of trees by smallholder farmers

A Survey on smallholder farmers in two communities (Gadid and El Mileah) in the Kosti Province of Sudan was carried out. The province lies 300 km south of Khartoum, between 12° 00' and 14° 00' N in latitude, and 32° 00' and 32° 40' E in longitude. Data were collected using a pretested questionnaire in addition to Participatory Learning and Action (PLA) approach. The questionnaire was designed to obtain information on farm management practices, tree diversity and their use of tree products. A total of 121 farmers were randomly selected for the survey. Descriptive statistics (SPSS) were used to analyze the management systems, needs, interests, and awareness of forest importance. The questionnaire was supplemented with the researcher's observation and informal discussions with local residents, in addition to discussions with key informants.



Fig.2. Location of research countries and sites

Table 3. Description of climate change vulnerability data and adaptation approach used in the different studies

Study	Key climate stress	Key non-climate stress	Projected climate risks*			Impacts	Study approach for adaptation
			Average annual P	Projected changes in P	Average annual T		
I	Erratic rain, drought, flood, storms (wind, dust and fire), high temperature	Poverty, policies, deforestation	600 to 900 for BF, 1100 to 2000 for Ghana	Decrease in BF 7.3% by 2050 General decrease by 2100 in Ghana	27 to 29 for BF >24 for Ghana	1.7 by 2050 For BF 2 to 3 by 2100 For Ghana	Scientific recommendations to help forest adapt
II	Drought, high temperature	Poverty, deforestation	250 to 350	Decrease of 6mm/month by 2060	27	1.1 to 3.1 by 2060	Resource use and management by vulnerable farmers
III	Erratic rain, drought, high temperature	Poverty, deforestation	200 to 361	Decrease of 6mm/month by 2060	27	1.1 to 3.1 by 2060	Designing responsive NAPA projects for poor vulnerable farmers
IV	Erratic and late rains, high windstorm, high temperature	Poverty, deforestation	1500 to 1700	General decrease by 2100 for Ghana	26 to 30	2 to 3 by 2100	APF features for formulation of an adaptation strategy
V	Flood, drought, high temperature	Poverty, deforestation	2000	Slight increase of 182 by 2100	24.9	3.5 by 2100	Multistakeholder priority sector for adaptation in forest ecosystems

*Data for temperature and precipitation are not consistent for all the studies because different countries used different models, years, measurements and presentations. BF-Burkina Faso, NAPA- National adaptation programme of action, APF-Adaptation policy framework

Source: Partly from field work, meteorological departments and literature (NAPA and Initial National Communications to UNFCCC)

Table 4. General data on forest governance in the different studies

Study	Key resource	Forestry domain	Governance strategy/ mechanism	Management right	Access/use right	Duration of rights	Relation to forest policy and sector
I	Forest resources	Natural and Planted forest	Comanagement State-market	State- dominated	State- dominated	Open ended	Income generating products are priorities
II	NTFPs	Community, Agro-forestry	Community-based	Farmer and Community-based	Farmer / community	Generation to generation	*Less crucial- NTFPs subsistence dominates commercial use
III	Gum arabic	Agroforestry	CBNRM Community-market	Farmer-based	Farmer	Generation to generation	Vital- gum is a major income source of forest sector of Sudan
IV	Timber, crops	Plantation (Agro)forestry	Comanagement State-market	Farmer- dominated	Farmer- dominated	25 years	Vital – MTS is a very functional programme with community involvement
V	NTFPs	Natural forest	Community-market	State- dominated	Farmer- dominated	Open ended	*Less crucial- NTFPs has growing markets but weak institutions

*Priority for vulnerable poor communities but far less importance in forest policy priorities

The PLA techniques involved the use of particular mapping exercises and transect walks (Chambers, 1992), which served to collect information in a participatory manner on farmers' observations and knowledge about their landscape particularly about plant and tree resources (Dovie, 2003). This transect consisted of walking from one end of the village to the other, which facilitated the identification of zones, contrasts, changes, conditions and physical features such as soils, trees, crops and buildings in the village environment. This technique also served to verify data collected from the local community and to check the accuracy and validity of information gathered from the household questionnaires, key informant interviews, and also secondary data.

The PLA approach was also intended to supplement the information gathered by using the household questionnaire. In completing that questionnaire villagers were asked to work in groups in order to give interviewees the chance to express themselves freely on issues under investigation and to discuss amongst themselves the problems or opportunities they might have.

Study III: The role of past agroforestry experiences in the design of tree related adaptation projects

The study was carried out in the 'gum arabic belt' of Sudan. Data were collected from Um Rwaba locality and Kosti locality. A representative community/sample from each of these two localities was selected to be compared against one another to determine the differences between locations in the Gum belt (Table 5). Gum arabic agroforestry is the dominant and traditional production system in all the study sites. These study sites represented a classic example of tree planting experience in acutely vulnerable areas in Sudan with its frequent droughts and high temperatures coupled with desertification, deforestation, and land degradation.

Table 5. Key characteristics of study communities

Um Rwaba Locality (Um Gazira, Um Seriha, Amanala)	Kosti Locality (Jogup)
<ul style="list-style-type: none"> • Main income: gum arabic, groundnut and sesame • Sandy soil • Major gum producing area • Strong gum association: 111-500 members / association • Drought, deforestation and land degradation • Major tree project: UNSO-FNC 	<ul style="list-style-type: none"> • Main income: sesame and off farm jobs • Clay soil • Minor gum producing area • Weak or no gum association • Drought, deforestation and land degradation • Major tree project : FINNIDA-FNC

In the study sites, 137 smallholder farmers whose principal activity was gum arabic production and who had participated in one or more tree planting projects in the past were surveyed. Data were collected using a pre-tested semi structured and open ended questionnaire. Detailed information on household characteristics, tree and land ownership, farmers' opinions on tree planting projects and their role in reducing the vulnerability to climatic and non-climatic stresses were obtained. Group discussions and focus-group discussions were held with farmers and local government officials in all the sites to understand further the tree related issues affect the vulnerability of farmers to climate change. To validate and analyze the views expressed by farmers, discussions were held with 15 other experts at state, national and international institutions in Sudan.

Study IV: Compatibility of plantation (agro) forestry with features of an adaptation strategy

The study was conducted in communities involved in taungya plantations (MTS) in three forest reserves namely: – Opro, Afram and Asufuo in the transition zone of Ghana. Data were collected in English from farmers and forest officers/managers by using: an open interview, discussions and also a pre-tested semi structured questionnaire. Information was collected on, vulnerability, policy and socio-economic issues related to taungya practice in Ghana. Meetings and interviews were arranged with farmers, regional development officers, district plantation development officers and officials from the land allocation and taungya management committee. Information was collected on the environmental changes, risks and hazards in their locality in addition to perceptions about the links between MTS and relevant policies and the policy instruments. An example of the socioeconomic data collected include: the area under MTS, crops grown, production costs and farm maintenance costs, annual outputs of crops cultivated, unit price and gross revenue per commodity, non-financial benefits of MTS and the extraction of firewood. Policy and vulnerability aspects were analyzed qualitatively whereas both descriptive tools and discounted cash flow techniques were used to analyze socio-economic field data.

A financial analysis was carried out to estimate the benefit-cost ratio (BCR), the net present value (NPV), the internal rate of return (IRR) and the pay-back period of MTS. Different scenarios were used to ensure a comparison of profitability in MTS. The first scenario included crops and trees, the second scenario included trees only whereas the third scenario included crops only over the complete MTS rotation period of 25 years.

Generally, a project may be considered for investment if the critical minimum value for BCR is greater than one (BCR is >1.0), which indicates a profitable venture. NPV only tells us how much the expected present profit could be earned from the investment and the project should be carried out if the NPV is positive ($NPV > 0$). The IRR is used to assess the viability of the projects. The decision rule in this approach is to accept those investments that have an IRR greater or equal to market rate of interest. These are computed mathematically using the equations below:

Benefit cost ration (BCR)
$$BCR = \frac{\sum_{t=1}^n \frac{B_t}{(1+r)^t}}{\sum_{t=1}^n \frac{C_t}{(1+r)^t}}$$

Net present value (NPV)
$$NPV = \sum_{t=1}^n \frac{(B_t - C_t)}{(1+r)^t}$$

Internal Rate of Return (IRR)
$$IRR = \sum_{t=1}^n \frac{(B_t - C_t)}{(1+r)^t} = 0 \quad IRR > r$$

Where

t = 1, 2, ...n

r = Discounting factor

B_t = Total income stream from the system in year t,

C_t = Total cost incurred on the system for year t,

Study V: The role of markets on NTFPs and the implications for climate change adaptation

This study was conducted at two levels. First, it was conducted at the national/regional level in the Congo Basin where multiple stakeholders were engaged, identified and set, through a participatory process, their adaptation priorities for the interventions and their implementation. Second. The research was at the level of the localised case studies in both the Equateur and Bandundu Provinces of the Democratic Republic of Congo. Data were collected from eight markets, five in 'Equateur province' and three in 'Bandundu province'. Selection of markets were based on their roles in the assembly and distribution of NTFPs, the presence of marginalised and vulnerable groups such as the Bantus and/or Pygmies, their accessibility, and their appeal to rural communities and urban populations. In each market, traders were selected randomly to administer a pre-tested semi-structured questionnaire. A total of 212 local traders of both sexes who were involved in the NTFP trade were surveyed. Data on the following were collected: prices of products along the value chain, volume of products traded and socioeconomic characteristics of the people involved in the NTFP trade. Both qualitative and quantitative (statistics) methods were used to analyze the collected data.

4. Results

4.1. Climate change adaptation actions in forest management (Study I)

This study shows that current forest policies in Burkina Faso (1998 National Forest Policy and 1997 Forestry Code) and Ghana (1994 Forest and Wildlife Policy-FWP) lack clear objectives to address climate change adaptation (and mitigation). Existing forest policy instruments, programmes and projects (Table 6) in addition to managers already have some of the necessary management activities in place to ease anticipated adaptation actions of forest ecosystems in the face of climate risks (Table 7). Effectively managing and implementing these policy programmes would likely determine the level at which management interventions can facilitate the adaptation by the forest managers to climate change risks.

Table 6. Examples of selected topics and relevant responses in Burkina Faso and Ghana

Topic	Example of Policy, Law, Strategies, Programme or Project	
	Burkina Faso	Ghana
Management of forest genetic diversity	-Section 2.1.2 of forest policy -Presence of seed banks for ex-situ conservation (ineffective) - Rely on forest reserves and agroforestry for in-situ conservation	-Section 3.2.2 of forest policy -Presence of seed banks for ex-situ conservation (ineffective) -Rely on forest reserves for in-situ conservation
Forest fires protection	-National strategy for wildfire management in rural areas -Articles 52, 53, 88, 258, 259 and Law No 006/97/ADP -Presence of few projects	-National wildfire management policy -Articles 5.3.11 -Forest Protection Act 624 of 2002 -Presence of few projects -Community fire squad
Forest regeneration/silviculture	- Articles 8, 13, 14, 45, 258 of forestry code -Annual reforestation and afforestation programmes	- Sections 5.2, 5.3.8, 5.3.9, 5.5.6 of forest policy -Timber Resource Management Amendment Act 617 of 2002 - Annual reforestation and afforestation programmes
NTFPs	-Policy/project focus is on game - Section 2 of forestry code -Article 56 of forest policy	-Policy/project focus is on game - Section 2.3, 2.4, 4, 5.2, and 5.4 of forest policy

Table 7. Adaptation actions in tropical forest management under climate change

Management area	Adaptation action	Country situation			
		Burkina Faso		Ghana	
		On paper	In practice	On paper	In practice
Tree genotypes	Plant suitable, adaptable and resilient tree genotypes that are resistant to pest, drought and wild fires	Yes	Low	Yes	Low
Forest protection	Put in place forest fire and pest management activities, build fire breaks to reduce disturbance, restore destroyed forest and protect trees against diseases	Yes	Low	Yes	Medium
Tree regeneration	Use artificial regeneration, assist natural regeneration, control invasive species and use drought tolerant genotypes	Yes	Medium	Yes	Medium
Silviculture	Selective removal of poor adapted trees, reduce rotation period, manage forest density, species composition, and forest structure to control disturbed stands	Yes	Medium	Yes	Medium
Forest operations	Increased logging from disturbed stands, forest carbon management, reduce impact logging, maximise landscape connectivity	Yes	Low	Yes	Low
NTFPs (excluding game)	Minimize habitat fragmentation, conserve biodiversity, maintain primary forest, and diversity of functional groups	No	Low	No	Low

'On paper' is based on current forest policy and laws. 'In practice' is based on review of programmes and projects and discussions with knowledgeable individuals. The level of country situation is based on a national scale of High, Medium and Low.

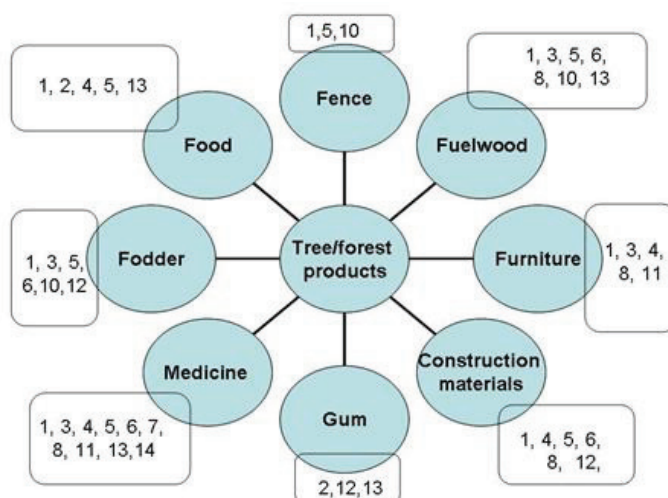
Table 8. Tree management practices to secure improved yields as indicated by smallholder farmers

Village	Frequency	Management practices to secure improved yields						Total
		Natural regeneration	Artificial regeneration	Coppicing	Pollarding	Harvesting selected tree products	Harvesting according to tree condition	
Gadid	Count	22	18	9	12	9	3	73
	% within Village	30.1	24.7	12.3	16.4	12.3	4.1	100
El Mileah	Count	20	13	2	4	5	4	48
	% within Village	41.7	27.1	4.2	8.3	10.4	8.3	100
Total	Count	42	31	11	16	14	7	121
	% between villages	34.7	25.6	9.1	13.2	11.6	5.8	100

4.2. Smallholders' use and management of tree resources (Study II)

Smallholder farmers in the study areas used different tree species and forest products to meet different subsistence and income needs (Figure 3). Of the 121 households surveyed, a majority of the farmers used forest products for fuel wood (98%), fodder (89%), gum (74%), construction materials (52%). Other important uses also included sources of foods (47%) and medicines (37%). Farmers identified 20 different tree species in the study area that are harvested from various niches within the forested landscape. As many as 97 per cent of farmers identified *Acacia senegal* and 69 per cent identified *Acacia nubica* as the most commonly used species. Other useful species identified that have disappeared from the study area are: *Adansonia digitata*, *Grewia tenax*, *Salvadora persica* and *Capparis decidua*. According to the farmers over-harvesting and poor regeneration were responsible for their extinction.

A majority of farmers (60.3%) in the study area relied on artificial and natural regeneration as a management practice for the long-term survival of their tree/forest resources (Table 8). These practices include the protection of young trees from livestock, wild animals, fire and human interference. Before the process of regeneration, farmers select the 'best-looking' trees for seed production, by placing particular emphasis on disease-free trees with large crowns. Site preparation options include weeding, cutting and burning. Farmers practice selective harvesting that leaves behind a certain proportion of fruits on trees both for future harvest and as future seed banks. Pollarding on selected mature trees, to provide *inter alia* firewood, stimulate coppicing and regeneration. According to farmers, drawbacks to natural regeneration include insufficient moisture for germination, insect pests, competition with other vegetation for soil nutrients, less genetically improved seeds, and the fact that farmers have little or no control over spacing between trees or stocking levels, so often leading to very uneven tree distribution.



1=*Zizyphus spina-christi*, 2=*Acacia senegal*, 3=*Dalbergia melanoxylon*, 4=*Cordia sinensis*, 5=*Balanites aegyptiaca*, 6=*Dichrostachys cinera*, 7=*Acacia mellifera*, 8=*Acacia nubica*, 9=*Leptadenia pyrotechnica*, 10= *Prosopis juliflora*, 11=*Azadirachta indica*, 12=*Acacia nilotica*, 13=*Acacia seyal*, 14=*Calotropis procera*

Figure 3. Uses of different tree species by smallholder famers

4.3. Tree planting and climate change adaptation in Gum belt of Sudan (Study III)

Using farmers' tree planting experience as a proxy for tree planting adaptation projects, the results show that much focus should be laid on the concerns held by farmers such as impeding resilient livelihoods, resilient environment or supportive governance (Table 9). This study acknowledges that the experiences highlighted may not cover the widest range of possible experiences and issues in past tree planting activities in Sudan, but it does provide useful indications on the issues to be addressed or captured during the design of tree planting adaptation projects. From an environmental perspective, the numerous services provided by *Acacia senegal* and other tree species especially during and after the Sahel droughts, ranging from gum arabic, firewood, soil fertility, wind breaks, soil stabilization etc. are well recognised by farmers and their government. Livelihood needs remain the most crucial concern of farmers, especially the gap filling cash-flow role of gum arabic income during the dry season when there is no income from other agricultural crops. From a governance perspective, those institutions that are supposed to support farmers livelihoods instead obstruct the capacity of farmers to adapt to various stresses. Heads of the gum arabic associations represent elite groups with powerful networks. They have little or no motivation for negotiating gum arabic prices on behalf of farmers who have low bargaining power. This lack of bargaining power is due to the farmers' immediate need for fast cash and their ignorance of the annual floor prices. This obstacle reflects the adaptation priority or entry point for tree related interventions that aim at increasing the resilience of vulnerable farmers and (agro) forestry systems to climate risk.

Table 9. Outcome of factors based on past tree planting experience of smallholders in relation to goals of successful adaptation projects

Factor	Relation to goals of successful adaptation		
	Resilient livelihood	Supportive governance	Resilient environment
Gum producer price	--	--	0
Rainfall pattern	-	-	-
Extension services	+	+	+
Locust attacks	-	-	-
Micro credits situation	+	+	0

(-- = high level of negative influence, - = low level of negative influence, 0=neutral influence, + = low level of positive influence, ++ = high level of positive influence)

The past experiences of farmers in the gum belt show that the most important factors related to tree planting and maintenance include the producer's selling price of gum arabic (86.1%), drought/rainfall pattern (69.3%), and locust attacks (50.4%). The fluctuating producer price for gum over the years had an important effect of motivating farmers to engage in planting and maintenance of *Acacia senegal* as a more attractive livelihood option over other sources of income (Table10). Some farmers in Um Gazira and Amanala reduced the level of tapping or stopped tapping altogether *A. senegal* trees whereas others in Jogup stopped planting due to the low prices of gum arabic. Instead farmers focused on cultivating agricultural crops, especially sesame, groundnuts, and Roselle. There was a high demand as indicated by good market prices and immediate cash rewards for these crops, which realized as a major source of income (47.6%) for farmers. In 2010, 2006 and 2002, study area farmers sold a kilo of gum arabic at about SD 60-

70, SD 250, and SD 70 respectively. The high price in 2006 reflected the temporal liberalization decision taken by the government in 2003 and 2004 to issue licenses to Sudan-based gum processing companies that led to competition among buyers that translated into high gum producer prices. With the exception of the price in 2006, intermediaries (middle men) buy gum arabic for less than the floor price from farmers and then sell it onto the auction market at El Obeid from where the gum arabic is then exported by the GAC. The floor price is a government policy to ensure a minimum buying price to the farmer and it is announced annually. It is the amount left after deducting from the export price the estimated cost of cleaning, handling, preparing and transporting the gum for export, in addition to the taxes, insurance and GAC profits.

Table 10. Income sources of farmers

Source of income	Study communities				All sites (%) (n=137)
	Um Gazira (n=33)	Um Seriha (n=45)	Amanala (n=28)	Jogup (n=31)	
Agricultural crops(%)	41.5	56	39.6	49	47.6
Gum arabic(%)	23	16.7	24.3	0	16
Livestock(%)	17	4.4	12.9	12	10.9
Others *(%)	18.5	22.9	23.2	39	25.5
Total (%)	100	100	100	100	100

*Others include jobs such as gum tapping, driving, building, petit trading, tailoring, guards, bakery worker, painting, butcher, land leasing, family support, etc

Poor and changing rainfall patterns with all the associated uncertainties of its distribution were perceived by a majority (69.3%) of the farmers to increase tree and seedling mortality rates. The seedling mortality rates affect the growth and establishment of tree stands after planting. Moreover, farmers and forest officers rely on rain fed tree planting. The month and year a tree is planted is crucial for its long term survival. Years with relatively good rainfall, as indicated in Table 4 (e.g. 2007, 2006), are generally favourable to tree planting activities, with a risk of flooding and water erosion whereas years with droughts such as that in 1990 are costly in terms of irrigation and not favourable for tree planting activities. Farmers attributed tree mortality and low or no gum production to recurrent droughts over the past decades. In Jogup, farmers recall 1973-74, 1984, 1992, 1998 and 2002 as major drought years whereas farmers in Um Gazira, Um Seriha and Amanala similarly indicated the early 1970s, mid 1980s, 1992 and 2002 as being drought years. In a normal rainfall year farmers, with the support of forest officers, check the soil for water before tree planting commences after two to three rains usually between the months of May up till September.

In the Sahel tree locust (*Anacridium melanorhodon melanorhodon*) attacks were reported by half of the farmers to have destroyed their gum gardens (*A. senegal*), decreasing gum yields and income. These attacks occur almost on a yearly basis and the Forest National Corporation and the agricultural departments rarely provide insecticides to spray infected plants. Farmers use traditional techniques to fight locust infestations. They dig trenches or tunnels around the trees and set fire to the tunnels. The wingless nymphs fall to the ground and when they jump they usually fall into the tunnels where they are destroyed in the flames.

4.4. Supportive features of MTS of Ghana to adaptation (Study IV)

This study shows that MTS in the transition zone of Ghana seems to incorporate most of the elements of an adaptation strategy (Table 11). MTS is not perfect, so addressing its challenges and shortcomings is essential as for any other adaptation strategy. The government of Ghana seems to have a strong interest in revenue-generating forestry activities with high financial returns and has given a high priority to the implementation of a plantation development programme such as MTS in its forest policy strategy. This shows that a government's priorities can influence the implementation and success of an adaptation strategy. The provision of fertile arable forest land for food crop production under the MTS represented the most urgent and important issue for many vulnerable poor farmers. MTS also provides the opportunity for farmers to extract firewood during land preparation without the speeding up of deforestation. With improved food security and livelihood, communities stand a better chance to withstand the present impacts of climate change. This in turn forms the basis for reducing vulnerability for future climate change.

Table 11. Relating features of a climate change adaptation strategy with MTS in Ghana

Indicative features of an adaptation strategy	Thematic area	Example from MTS in Ghana	
		Situation	Comment
Stakeholders engagement	Policy	Present	Farmers' involvement and views are central to decision making under MTS.
Policy and strategy on climate change	Policy	Absent	Development of climate change strategy in forestry is in process and MTS is mentioned
Vulnerability to climate risks	Vulnerability	Present	MTS areas face drought, bushfires and desertification
Long-term goal	Policy	Present	Policy instruments have been put in place
Short, medium and long-term benefits	Socio-economics	Partially present	Short term benefits exist. Long term benefits depend on effectiveness of policy instruments
Support development goals	Policy	Present	MTS contributes to food security and poverty reduction
Cost effective	Socio-economics	Present	MTS benefit covers investment cost (BCR>1)
Non-financial benefits	Vulnerability / Socio-economics	Present	MTS provides household subsistence food and environmental services
Synergy with other conventions and development	Policy	Present	MTS supports climate, desertification and partly biodiversity conventions
Monitoring and improvement	Policy	Partially present	Influenced by the effectiveness of policy instruments

The BCR of the MTS shows that it is cost effective with the value of its benefits exceeding that of its cost (BCR>1). This makes MTS a financially attractive investment as an adaptation strategy and arguably represents the reason for continuing the adaptation process by all the stakeholders that are involved. Table 12 has a summary of the results from the investment appraisal of a mean hectare of MTS under three different scenarios. The net present value (NPV) at 15% discount rate was positive and the internal rate of return (IRR) was found to be 17.77%. The findings of the study compare favourably with findings from a similar study. In that study, Agyeman et al. (2003) used a discount rate of 10% and estimated that 16.2% as the IRR for MTS in a study that covered several districts in Ghana. According to the Adaptation Policy Framework, (Perez and Yohe, 2005), much could be learned for the implementation decision on adaptation policy by repeating the same benefit cost analysis on the same project using similar baseline information. Under such conditions higher economic benefits could expand sensitivity towards and increase benefits for anticipated climate change.

Table 12. Summary of financial analysis (in US\$) per hectare under various scenarios

Project performance indicators	Scenario 1 Food crops + trees	Scenario 1 Trees only	Scenario 1 Food crops only
NPV (15 % discount rate)	20 362.00	20 553.60	3.76
IRR (%)	17.77	17.80	16.88
Total discounted cost (15%)	155 103.43	153 112.55	3 986.66
Total discounted benefit (15%)	175 080.92	173 666.15	3 990.43
BCR (discounted)	1.1288	1.1342	1.0009
Total undiscounted costs	1 339 221.92	1 337 355.12	15 109.18
Total undiscounted benefits	3 755 684.55	3 753 955.44	13 038.35
BCR (undiscounted)	2.80	2.81	0.86

The investment decision and implementation of MTS is guided by Ghana's plantation development programme by using different policy instruments (Table 13). The effective use, enforcement and compliance of these instruments could support MTS as an adaptation strategy. At the national level, legislative instruments such as the Timber Resources Management Amendment Act of 2002 and the Forest Plantations Development Funds Amendment Act of 2002 strengthen tree ownership rights of farmers and provide incentives for MTS. Farmers have a share in the benefits that will arise from the sales of harvested timbers in the future. Benefits will be shared as 40:40:20 per cent ratio for farmers, forestry department and local community respectively.

At the local level, land allocation and the taungya management committee combined (LATMC) promotes a high level of information exchange between stakeholders. LATMC also distributes lands to taungya farmers and ensures the compliance of the farmers and the FC to the agreed obligations and activities. Institutional actions have resulted in the formulation of a wildfire

policy and include community fire squads, due to the high vulnerability of the transitional zone and northern parts of Ghana to annual wildfire outbreaks. Forest fire management especially through the ‘Community Fire Volunteer’ is an adaptation measure to increase the resilience of forest ecosystems to fire disturbances, and thereby reduce the vulnerability of forest ecosystems in the north and transition zone of Ghana. Nevertheless, challenges remain on the limited human, material and financial resources available to fight the frequent and large scale forest fires.

Table 13. Policy instruments guiding the implementation of MTS

Instruments	Instrument scale		Instrument effectiveness
	Calibrations in years	Spatial scale	
2002 Timber Resources Management Amendment Act	25	National	Moderate
2002 Forest Plantations Development Fund Amendment Act	25	National	Moderate
Land allocation and MTS management committee	2-4 (periodic)	Local	Moderate
Fire volunteers and management plan	1 (periodic)	Local	Moderate

4.5. Marketing of NTFPs and adaptation to climate change in DRC (Study V)

The stakeholder prioritization process identified the most important forest-based sectors that corresponded to development sectors such as household energy, health, potable water, and food security (Table 14). Sectors were linked to the provisioning of services and ecosystems that characterize household goods. The outcome of the prioritized sectors undoubtedly emphasizes the livelihood challenges and the recognized vulnerability of livelihood system in the region. NTFPs for food and wood fuel energy represented the most important forest-based sector for adaptation. Among the NTFPs collected and commonly commercialized are, *Marantacea* leaves, *Gnetum* spp. (Eru or Fumbua), *Dacryodes edulis*, caterpillars, mushroom/edible fungi, fish (smoked and fresh), bush meat and charcoal (makala).

Table 14. Adaptation priorities for Congo Basin forests

Democratic Republic of Congo-DRC	Regional level (Central African Republic, DRC and Cameroon)
Food (NTFPs)	Food (NTFPs)
Energy (wood fuel)	Water
Water	Energy (wood fuel)
Health (medicinal)	Health (medicinal)

Women predominate in the trade of NTFPs. Of the 212 traders sampled in Bandundu and Equateur provinces 79% and 63%, respectively, were women. Markets play important roles and much the swapping the safety nets of commodities for safety net of cash liquidity occur in markets. A substantial volume of NTFPs harvested contributes significantly to household income. The study showed that selling six NTFP lines earned a mean monthly revenue of US\$225. Charcoal understandably represented the largest removal of carbon from the system. Its production season lasts for almost the entire year. This was closely followed by palm wine. Charcoal and palm wine, with their higher total income returns in both provinces, involve destructive collection methods that adversely affect forest structure and integrity. The collection of *Gnetum* spp. represents defoliation, which, if done sustainably, will allow for regeneration. Although NTFP trade generates income, this study observed that the distribution of income along the product's value chain can still leave the producer or the farmer who does the actual foraging highly vulnerable. There were significant differences between what the farmer received for the wholesale and retail prices for a chosen commodity for all the NTFPs. The margin in some cases almost doubled retail prices are considered too high even after factoring in the transaction costs. Market values are sometimes determined by what happens in other sectors, which complicates the planning process. For example, a bumper harvest of groundnut easily results in an increased market value of *Gnetum* spp. because of the latter's use in preparing the local dish. Market activities are sometimes separated along gender lines, with the women dominating the retailing of some of the NTFPs, whereas the men dominate the wholesale activities. The distribution of market benefits along such lines may also explain the gender differentiated vulnerability. Such information is crucial in planning adaptation strategies in such communities.

5. Discussion

5.1. General overview

Mounting evidence from NAPA, IPCC, and National Communications with the UNFCCC show that climate change is already hitting the poor in Africa and signals an urgent need for appropriate responses and interventions in order to minimize their vulnerability. Many African countries are amongst the poorest and most disadvantaged in their development process. They are also the most vulnerable countries in the world. The physical, political and socio-economic characteristics predispose them to be more vulnerable to adverse effects of climate change. Poverty in SSA is acute in rural areas as it affects about 90% of the rural poor (Oksanen et al. 2003). Three of the four study countries; Burkina Faso, DRC and Sudan, are classified by the United Nations as 'least developed' in the world and are in need of the highest degree of attention on the part of the international community. Ghana, the fourth study country, is the exception to this. Burkina Faso is land locked, and together with Ghana and other Sahelian countries like Sudan is threatened by drought and desertification. These Sahel countries are also experiencing a significant reduction in rainfall and a southward shift in forest flora and fauna. Moreover, Sudan and DRC are or have been badly affected by conflicts whereas many communities in Ghana and Burkina Faso have been greatly affected by flooding events over the last decade.

For the past four decades, climate variability and change have been manifested mainly through intense and frequent extreme climate events of droughts, floods, windstorms, forest fires and temperature extremes. All these events speed up the natural degradation of resources and make sectors such as water, forestry, agriculture and livestock most vulnerable to the effects of climate change. These vulnerable sectors, especially agriculture, are often badly affected by recurrent droughts and floods through the extreme annual variability in the amounts, timing and location of rainfall. These unreliable and inadequate rainfalls and rainfall patterns result in poor crop and other natural resource productivity that threaten food security, livelihoods, and increase poverty and famine. The effects of these push vulnerable households, groups and communities in search of alternative and additional livelihood means especially through the use of provisional forest ecosystem services.

Forestry, forest sector and forest ecosystem services have the potential to support community and society adaptation to the impacts of climate change by strengthening livelihood opportunities, protecting the forest and environment by using policies and governance mechanisms that are appropriate and favourable especially for local communities. The forest sector respectively contributes 3, 5, 6, and 3 per cent to the gross domestic products (GDP) of Burkina Faso, DRC, Ghana and Sudan (Birinkorang 2001, FAO 2003b, MECV 2004, Debroux et al. 2007). In the DRC and Ghana these figures reflect the income from the sales of timber. In Burkina Faso, it reflects income mainly derived from organized commercial exploitation of firewood and the sales of the NTFP Shea butter, whereas in Sudan it mainly reflects the sale of timber and gum arabic. This corroborates the findings of Lange (2004) on the values assigned to forest within national accounts in most developing countries that are generally limited to timber and other marketable goods. However, forest sector contributions to GDP of the study countries represent an underestimate because they often exclude subsistence uses and other benefits that accrue locally to forests dwellers and users.

Increasingly, some governments in Africa are showing signs of willingness to support policy and governance reforms that are favourable for local communities over the use, management and benefits of forest resources. These governance reforms are vital for the improvement of the

adaptive capacities of vulnerable poor communities (Seppala et al. 2009). Forest governance in Ghana is increasing characterized by local forest ownership and the improving opportunities for livelihood enterprises under the MTS (Study IV). In Burkina Faso, organized and sustainable firewood exploitation in forest reserves is controlled and managed by communities. However, in some cases, state policy works against forest-dependent communities by decreasing their adaptive capacities to the impacts of climate change. An example of this is the gum arabic sector of Sudan in which the state has the monopoly to export gum arabic. This monopoly can have a negative influence on the gum prices of farmers and their capacities to adapt to impacts of climate change. Market actors obtain far more benefit than that obtained by the vulnerable poor farmers from the sales of forest products (Study III and V). Forest governance reforms that enforce and favour improved floor or minimum prices for farmers are a platform from which to increase farmers' resources so that they can use these to adapt to climate change.

The impacts of climate change on forest ecosystems and their services, coupled with increased forest management challenges threatens the useful role of forest ecosystem services for communities' adaptation. Climate change threats in the form of changing precipitation, storms, and increased temperatures among others are commonly manifested through wild forest fires, shifts in forest ecosystems, more and severer insect infestations, an increase in invasive species etc. On the other hand, management challenges that face the forest sector in the study countries include the following: depleting state of forest resources from constant deforestation activities, high livelihood-dependency on forest products for subsistence and income generation, changing and/or conflicting values and ownership put on forestry by different actors, in addition to the sustainable utilization, conservation and development of these resources for present and future generations. There are other management challenges in these study countries.

The high rate of deforestation in Africa threatens the provision of forest ecosystem goods and services for communities' adaptation. The annual deforestation rate of Burkina Faso, Ghana and Sudan, for the years 2000 to 2010, ranges from 50 000 to 250 000 ha, whereas that of DRC ranges from 250 000 to 500 000 ha (FRA 2010). This indicates that valuable forest resources are lost every year to the communities' adaptation and livelihoods. As a response option in some areas, farmers through forestry and agroforestry practices are actively involved in the form of replanting and replenishing the depleting forest assets. The objective is to regain their assets for livelihood and ecosystem adaptation. This is a common practice in the drought and desertification stricken gum belt of Sudan (Study II and III), the transitional zone of Ghana (Study I and IV) and Burkina Faso (Study I). In the case of large scale reforestation activities in these countries especially under project funding, farmers to a certain extent are supported technically by state forest management institutions through the provision of extension services.

For many local communities, forest resources represent their assets for livelihoods and their ability to adapt to climate impacts. For many people at the global level, forest especially with the current climate change discourse, represents a cheap and valuable sink and source for carbon. The global perspective will only make sense to many African local and indigenous communities only when they can actually reap the benefits in terms of livelihood from schemes such as REDD. Thus good forest governance, though challenging, must be put into practice.

5.2. Review of the study approach

The combination and use of different concepts from forest governance, climate change adaptation to livelihood dependence on a forest ecosystems services were found to provide an appropriate method for conducting a multidisciplinary climate change adaptation study in different situations. Climate change adaptation is location and situation specific with no unique approach. The present study required a multidisciplinary approach to align with and address the research problems that cross the borders of disciplines such as policy, law, forestry, agriculture, development, sociology and environmental sciences. The rationale of such an approach rests on the fact that problems related to forest governance and adaptation of socio-ecological systems are complex and cannot be solved from a single perspective or discipline's view. Moreover, the approach guided the methods and tools used. Different case studies were used as the research strategy and were guided by their respective conceptual orientations. Case study research provides deeper understanding of a context, is flexible and easily adaptable to new and emerging important issues and theories (Yin 1993).

Both qualitative and quantitative data collection methods and tools found to be appropriate were used for the case studies. These included a combination of interviews, group and focus group discussions, questionnaires, direct observations, participant observations, document analysis and expert consultation. The researcher took many roles depending on the tool or method used. These included being a facilitator or observer during group discussions, interviewer during interviews and evaluator during literature review. The concept of climate change was easily understood by farmers, during interviews and discussions, through farmers' explanation of causes of changes in their environment over time. This was then narrowed to climate-related impacts of environmental change such as drought, flood, wind, fire and dust storms. The methods used provided a way to put into effect the different concepts used in the study. The greatest advantage of the study approach is related to the way it required the researcher to carefully readjust the concepts, the scope and the boundaries of the study to reflect the situation on the ground. The study focused particularly on selected forest governance mechanisms and partnerships. One case (Study I) focused entirely on the management and implementation of selected forest policies. Forest governance focus of the study was then analysed with respect to adaptive capacity as a component of assessing vulnerability and forest-based livelihood assets under climate change.

Some parts of the case studies present forest governance as it is currently i.e. as a more or less static situation. This may be criticised as a limiting factor of the study approach (Amitage and Plummer 2010). The static governance picture presented reflects the outcome of the evolution of governance interactions at various scales. For example MTS in study IV is the outcome of the many years of revision and piloting of workable community-led forest governance approach in plantation development under Ghana's forest policy programmes. In Sudan, the current level of support of gum agroforestry to livelihood improvement and environmental protection is a reflection of the outcome of many years of interaction between powerful national levels governance actors since the great Sahel drought of the 1970s and 1980s.

All the case studies, with the exception of study I, were built around smallholder farmers' use of forest ecosystem services in interaction with either state or market actors to increase their adaptive capacity and hence reduce vulnerability to the impacts of climate change. Smallholders' use of forest resources in almost all African countries has been in most cases limited to forest products other than timber i.e. NTFPs. However, NTFPs are diverse in nature, which is also reflected in the diversity of the case studies. Another approach would have been to take similar or comparable forestry activities in different locations or countries to analyse how they influence the

adaptive capacity of vulnerable groups. For example the study could have compared gum arabic production by farmers in different countries of the Sahel. However, this was not possible in the present study because the focus was instead on the supportive, most outstanding and potential forestry activities that align with climate change and adaptation actions.

Different forestry and climate change experts were consulted before selecting the specific case studies. Experts from the government, communities, NGOs and universities provided guidance to ensure that the objectives of the various case studies were relevant and dealt with priorities for supporting vulnerable poor communities and forest ecosystems to adapt better to the impacts of climate change. Study IV was operation-based on the outcome of a multi-stakeholder dialogue about priority intervention areas for climate change adaptation in the Congo Basin. Case studies were conducted in different countries because certain countries are associated with the development of specific forestry products or activities. Moreover, the more diverse and best forest governance regimes have a higher adaptive capacity and are very much needed to support the adaptation decision making processes in Africa. The present study could only cover a limited number of relevant forestry activities on the involvement of smallholder farmers' in: forest management and environmental change (Study II), NTFPs in the Congo basin (Study III), MTS (Study IV) and gum arabic (Study V), in addition to policy practices for the adaptation of forest ecosystems (Study I).

Study I reviewed forest policy contents in Ghana and Burkina Faso to illustrate forestry activities that are applicable and existing in different African countries. The forestry experts consulted during the study had little understanding in terms of activities that could help forest ecosystems to reduce vulnerability and increase their adaptation to impacts of climate change. This study drew largely upon the adaptation activities described in the scientific literature. However, that literature is based mostly outside Africa and on the temperate and boreal forests in the north. The case study focused on identifying relevant policy phrases, key indicative programmes, projects and activities. Important broader themes that are more useful at the policy level, which include: forest fire protection, genetic resource management and reforestation were identified. At the management and implementation levels, these themes could be further looked into with more detail perspective in separate studies. Study IV focus on one of themes - reforestation activities.

Study IV drew from the MTS as a reforestation activity in Ghana to analyse the vulnerability, political and socio-economic context. MTS is one of the most functional forestry activities under Ghana's forest policy that involves the active participation smallholder farmers. MTS has shifted forest ownership from government monopoly ownership to multiple and community based ownership. The depletion of timber resources and lack of capacity or willingness by many governments to replant degraded forest lands have impelled many governments including those of Kenya, Nigeria, Ghana and others to get into partnership with communities by introducing the traditional taungya system (TTS) as a viable option. This system has its pitfalls mainly in terms of mismanagement and benefit sharing. Recently in Ghana, the system has regained its momentum in terms of supporting livelihood opportunities and correcting previous mistakes, which has led to a change of name from TTS to MTS. Study IV has a huge potential for the adaptation of vulnerable socio-ecological system to impacts of climate change in the transition zones of Ghana and other African countries that have stated large scale reforestation as an adaptation activity. Additionally, other studies can be conducted mainly with the purpose of estimating the carbon stock of such system especially under REDD schemes. In this light, a more comprehensive study that tackles both adaptation and mitigation to climate change in addition to the original objective to replenish depleting timber stocks whereas providing livelihood opportunities under MTS may

be more useful. This will further highlight more understanding on synergies between mitigation and adaptation in forestry that is well recognised but less studied.

Studies II and III described the management of trees, their uses and the commercialization of tree products mainly gum arabic by some farmers in the gum belt of Sudan. Information from these studies predominantly covered the views of farmers who were more involved with the cultivation and commercialization of gum arabic. The studies were relevant in that they represented the views of the most vulnerable smallholder farmers. Study III represented a farmer-led governance situation where communities interacted both with the state (forestry department) and the market. Lessons from such case studies are relevant in other locations and countries where gum arabic or other NTFPs and traded or commercialized by farmers.

Similarly, Study V covered the safety net and climate change adaptation role of a mix of NTFPs traded by smallholder farmers in the DRC. Most of the farmers are highly marginalised and represent the indigenous group of people known as the Baka Pygmies who are predominantly located in the Congo basin countries of the Cameroon, Gabon and DRC. The approach employed in this case study blend livelihood, markets and climate change adaptation issues in a supportive role that does not follow any linear logical frame. Neither the livelihood approach nor the direct use of climate change vulnerability concept of exposure, sensitivity and adaptive capacity was strictly followed. Instead the stakeholders' adaptation priorities for the Congo basin forest set the research focus and activities.

5.3. Managing the adaptation of forest

Forest ecosystems that provide numerous product and services vital for human wellbeing are themselves vulnerable to the impacts of climatic change such as fires and droughts. This is a situation where adaptation becomes a necessity. It is common to find many scientific studies on adaptation activities in temperate and boreal forests mainly in the developed countries and some parts of Latin America (Amazonian forest) and Asia but hardly ever in Africa. Most of these climate change adaptation activities are also practiced in sustainable forest management in many parts of Africa but remain undocumented. The objectives of sustainable forest management are to maintain ecosystem processes by matching management practices to natural or expected processes. The effectiveness of such practices in Africa is another issue that requires a detailed case by case study. What remains very important is to educate decision makers and forest managers on those activities that can potentially support or hinder the adaptation of forest ecosystems to the impacts of climate change (Study I). In this case, management interventions can either potentiate forest ecosystems to become more resilient to climate related disturbances or facilitate adaptations in forests as the climatic parameters change over time.

Future predictions of IPCC Fourth Assessment Report (IPCC 2007) suggest that tropical forest ecosystems may not be resilient over time. However, short term evidence suggests mixed effects. Current climate change is inducing increasing CO₂ fertilization in tropical forest production. On the other hand, the Amazonian forest is in some parts experiencing changes in species composition as an indication of resilience to current changes (Malhi et al. 2009). Impacts of climate change on tropical forest ecosystems will have dramatic effects on the provision of ecosystem products and services in particular with a loss of biodiversity. The Loss of biodiversity at gene, species and landscape levels in different systems will mean less resilience and less flow of product and services and even more vulnerability to disturbances. Thomson et al. (2009) suggested ecological principles that can enhance forest resilience under climate change. These

principles include the following: maintenance of forest genetic diversity, maintenance of stand and landscape structural complexity, designing of national and regional planning for large scale landscape connectivity, maintenance of functional diversity in natural forests, controlling of invasive species, encouraging the use of native species, and the maintenance of biodiversity on all levels. Furthermore, factors that may contribute to the vulnerability or resilience of different forest ecosystems species might include but are not limited to species with limited dispersal ability, species with fragmented and isolated population, species with late successions, trees with abilities to tolerate increasing temperatures, thermal tolerance levels of animals etc. (Campbell et al. 2009).

Forest management interventions in many African countries face the challenge of helping forest ecosystems shift to a suitable location. However, forest ecosystems are already migrating with or without the help of management interventions. It is common to read in the NAPA outputs of many Sahel countries how precipitation has changed over time and the lower rainfall isohyets are generally moving southwards. In many of the cases, the southwards shift of the drier isohyets is accompanied by vegetation change and hence ecosystem shift. It was very common to hear from farmers during Studies II, III and IV that they have noticed the presence of tree species that were rather, in the past, common in other northern locations. Anecdotal evidence from farmers in the gum belt of Sudan show that *Acacia tortilis* and *Leptadenia pyrotechnica* are gradually but increasingly creeping into zones that were formerly colonised by *Acacia senegal*. Farmers attributed their observations mainly to changing environmental and climatic conditions. Similarly, the gum belt of Sudan is gradually shifting southwards into those states that have not produced gum arabic before. In Ghana, reclassification of national vegetation map is under discussion as the northern part, down to the transition zone has been badly hit by drought and desertification, annual forest fires, deforestation and general environmental degradation. Thuiller et al. (2006) concluded that 'the effects of global climate change and land transformation on wildlife communities may be most noticeable, not as a loss of species from their current ranges, but instead as a fundamental change in community composition'. That study was focused on national parks in Africa. Thuiller et al. (2006) also argued that latitudinal aridity caused contrasting latitudinal patterns with a westward range shift of species around central Africa, and an eastward shift in southern Africa.

5.4. Dependence of societal adaptive capacity on forest ecosystem service

The present study shows that forest ecosystems can contribute to the adaptation of a society mainly through the provision of timber and NTFPs. Ecosystems can also contribute to adaptation through structural defence against the degradation of natural resources, by the processes of desertification and soil erosion. Amelioration of degradation is very important especially in drought and desert stricken parts of Africa. However, timber and NTFP production is even more important from a livelihood perspective, which is why it has dominated major development goals in Africa such as the poverty reduction strategies. All the case studies with the exception of Study V considered both the production and amelioration of degradation as factors in the adaptations taken by those societies.

In case studies II, III, IV and V better livelihood opportunities emerged as the priority for the farmers. This implies that any action aimed at improving the adaptive capacity of vulnerable forest-dependent groups to impacts of climate change must focus on livelihood opportunities. In this light, it makes sense for adaptation interventions to tackle obstacles to livelihood opportunities as well. Such an approach may go beyond the normal locally focused natural

resources management and utilization to include actors in different sectors that are not normally recognized in the national climate change milieu. It includes in a broader sense governance challenges, inter-sectoral co-ordination, the role of markets and even politics to an extent. For example in Study V, the Gum Arabic Company of Sudan enjoys and wants to maintain its monopoly to export gum arabic from Sudan to the detriment of vulnerable poor gum arabic farmers in terms of low prices. Yet this monopoly arrangement has the support from the Ministry of Trade. In contrast, the President's office wants to encourage a free market with many companies being able to export gum arabic with the goal of boosting competition among gum dealers that may result in higher gum prices to the benefit of vulnerable poor farmers. At this level, the ability of these farmers to raise more gum income as assets for adaptation is at the mercy of the bigger players and national politics. Adaptation intervention in this sense is more than just 'the business as usual' reforestation of a degraded gum belt. Similarly in study V it was found that forest-dependent communities involved in the trading of NTFPs received far less income for the same commodity than other actors at the wholesale and retail levels. Adaptation interventions in this case may require involving other actors and factors that affect the livelihood activities of vulnerable groups.

Adaptation strategies that aim at protecting the environment and ecosystems was much appreciated by farmers and especially government institutions in the various studies. This is an area where funding agencies also gave a lot of their attention. After the great Sahel droughts of the 1980s, many reforestation activities have been funded to restore degraded environments and ecosystem services. In some of the study areas (Study I, II, III and IV) scattered trees on the landscape provided shade for both animals and humans. It was common for farmers to plant a few less commercial species of trees on their farmlands to act as wind breaks and also stabilise soils that were under the threat of sand encroachment. At the end of the day, some of the farmers also act as the agents of deforestation through excessive harvesting of trees and forest resources to meet their livelihood needs. Firewood and charcoal exploitation, medicinal plants, bush meat and wild food are all examples of basic livelihood needs of many vulnerable poor farmers. It is logical therefore to argue that without first meeting the livelihood needs of the current generation especially vulnerable groups, it may be even more challenging to conserve or protect the forest for the future provision of ecosystem products and services.

The implication for meeting forest-dependent livelihood needs of vulnerable poor groups in Africa is far reaching. The present study focused only on small groups of farmers in particular locations. However, there are many other categories of vulnerable poor group in Africa that highly depend on forest ecosystem services and are also affected by impacts of climate change. These poorest groups include among others, poor pastoral communities, urban poor people and landless migrants. In times of crisis such as during periods of flooding, drought and storms, these groups of poor people rely on forest products. Moreover, limited access to forest fodder by pastoral communities and to charcoal by urban poor might worsen their situation and increase their vulnerability. Many studies in Africa have shown that where access to forest products becomes marginalized, the adaptive capacity of the poorest people is reduced. In many of the case studies forest products came from forest reserves, forests outside of the reserves, scattered trees in bushlands on landscapes in addition to trees on farmlands. All these sources are considered in the present study as forest products.

The work of Eriksen et al. (2005) in Tanzania and Kenya shows that land tenure system and distribution affects access to the forest products by the vulnerable poor. Communities surrounded by uncultivated forest and bush land have more indigenous plant resources to use as adaptation assets during impacts of climate change. The nature of the surrounding vegetation types also

determines the kinds of products available for communities use. On the other hand, some aspects of existing forest policies increasingly undermine livelihood security by reducing access to livelihood resources. Many African governments have inflexible standardized rules on access to forest resources. However, *de facto* is not the same as *de jure*. For example, in Ghana the Forest Protection Amendment Act (Act 624) of 2002 restricts community access to forest products within forest reserves but in practice, many of the communities ignore the government laws and employ moderate local rules to access particular forest products. By contrast, government laws in Burkina Faso (Article 55-59 of the Forestry Code) allow community access to forest products mainly for subsistence.

Another example comes from the drought-prone Bushbuckridge in South Africa where women exploit shrubs and grasses from the forest to make handcrafted brooms that are then sold (Shackleton and Campbell 2007). These women, who are very poor, have no land, only limited assets, skills, education and income. They turn to the forest products and other natural products after experiencing hardship or shocks. Access to the shrubs was limited and determined by the personal friendly relation of the women with individuals and forestry companies who owned private lands. On the other hand, access to grass was less complicated and determined by the payments of nominal fees to forestry officials to harvest the grass from state owned forest lands. The latter was considered more secure for the women as it was supported by South African Forest Act of 1998 on the exploitation of forest products.

Access to other assets other than forest products is equally important for adaptation. In a study in Morogoro in Tanzania, Paavola (2008) argued that ‘there is no single solution, which will enhance adaptive capacity’. Vulnerable poor groups need access to markets, employment, public services and other complementary livelihood activities to enhance their capacities. Similarly, Tschakert and Dietrich (2010) pointed to the limited access to information, knowledge and climate change learning tools especially at the community levels in many African countries as major obstacles to building the resilience of institutions and socio-ecological systems.

5.5. Consideration of spatial and temporal scales

Spatial scale: The spatial scale of almost all the case studies was very small and localized. With the exception of study I, all the case studies covered the smallest local scale (village or community). Only Study I covered a broader national perspective in Ghana and Burkina Faso. The local scale focus is justified by the fact that adaptation actions occur locally either at the household or community level. However, vulnerability can be explained and described at various spatial scales ranging from household, community, local district, sub-national, national, sub-regional to even continent levels. For example, case study III was carried out in North Kordofan in the gum arabic belt that represents one of the most vulnerable areas in Sudan. Sudan being part of the Sahel region in Africa a continent that is very vulnerable to the impacts of climate change is one of the most vulnerable countries in the world (LDC).

The analysis of all the localized community-level case studies may greatly vary, if the scale was to changed either to a smaller inter- and intra-household level or to a bigger sub-national or national level. ‘Some collective adaptation actions enhance the livelihood resilience to climate change but others have negative spillover effects to other scales’ (Osbahr et al. 2010). The difference in scale must therefore be well understood during climate change adaptation decision making or interventions. In the broader perspective where a whole district or country are being considered as vulnerable to drought, the greater role of communities, district and national

institutions offers a better capacity to respond. This may also act as a proxy for the individual's ability to adapt to drought (Dougill et al. 2010).

The boundaries of different human spatial scales are not necessarily the same as those of natural, ecosystem or landscape boundaries. Humans depend on products and services from ecosystems and landscapes that cut across administrative and human boundaries. A good example is trans-boundary natural resources such as the Volta, Congo and Nile watersheds that cover many countries. Another example is the Congo basin forest that covers many countries. However, regional and international policy initiatives on trans-boundary resources must, adopt adaptive forms of governance. Moreover, they must focus on building the adaptive capacity of the poor and most vulnerable in society. They must also consider cross-scale dynamics of change, the interactions between multiple stressors, and longer term climate change (Bunce et al. 2010). Otherwise, these initiatives may end up promoting more risky and less diverse livelihoods.

At a smaller community scale, forest reserves traverse many communities and villages in addition to local administrative districts. Case study IV represents such example. Adaptation interventions and decision making in these situations might be better considering the ecosystem scale rather than the administrative scale, which is an argument put forward by the ecosystem-based adaptation approach. Natural resources governance in this sense may be challenged at the national level to do things differently with more horizontal and cross sectoral approaches and co-ordination. At the sub-regional level, nations that share trans-boundary resources have limited choices other than to work together as is evident in the Congo basin forest countries.

Temporal scale: Adaptation to climate change is a continuous process that may change over time with necessary adjustments. An adaptation process does not necessarily result in improved adaptation or adaptive capacity. The success or failure of adaptation processes might be analyzed in terms of short, medium and the long term, hence the sustainability of adaptation actions. It is also important to understand that the past and future climatic trends enable actors and administrations/decision makers to plan better and implement adaptation actions.

West African countries and those of the Sahel was where four of the case studies were conducted are known for having among the highest climate variability in the world (Wang 2004). The climate of West Africa is dominated by the seasonal movement of the West African Monsoon. West African countries and those of the Sahel respective climates experienced unusually high rainfalls in the 1930s and 1950s and a severe drought in the later part of the 20th century. The region saw a mean annual rainfall drop of 30% during the period of 1960s to 1990s with devastating effects on the local population (Hulme 2001). Although many governments and development agencies have funded reforestation and natural resources management activities since the 1980s as major response strategies to the great Sahel drought, many of the communities remain vulnerable.

Today, under the climate change convention, the need to address adaptation issues is well recognized and has gained momentum at various local, national and international levels. Community-based natural resource management (CBNRM), which is covered in the present study, represents one of the local level activities used to improve socio-ecological resilience to shocks. At the national and international levels, politicians and decision makers in many countries usually deal with the short term objectives. Consequently, they are more sensitive to and more willing to address the most pressing problems and the needs and expectations of their electorates. Many governments at the national level are making policies and some of which are

implementing NAPA. In the meantime the international community is engaged in discussing crucial issues such as the funding of adaptation actions in developing countries.

The short term and medium term impacts of CBNRM on the adaptation of vulnerable poor forest users is expected to maintain life-sustaining systems and generate income through short term employment in reforestation and afforestation programmes, agroforestry practices, and the marketing of forest products. These objectives indirectly improve food security, coping strategies and adaptive capacities. A study by Broekhuis et al. (2004) on urban-rural linkages and climate variability in Burkina Faso, Senegal, Mali and Niger suggested that climate change and further degradation of forest resources will affect the future woodfuel market in urban areas. The demand for woodfuel will continue to rise with the fast growing population and increasing rate of urbanisation.

On the other hand, with increasing droughts woodfuel supply will grow in the short term due to the increase in the availability of dead wood. In contrast, in the long term, woodfuel will become scarcer and more expensive in urban areas, which will increase the vulnerability of the urban poor. Short term adaptation plans on the site scale may also include the evaluation of forest management plans and activities for adjustments. The medium term can be assessed in the next five to 10 years. Activities at the national and international levels may include: the impacts of NAPA, and other ongoing adaptation actions and processes, how much the international community would have done in meeting their financial commitments to fund the under-resourced adaptation actions, practical integration of climate change issues into development and policy interventions (mainstreaming) etc.

CBNRM coupled with development and policy interventions along with the better availability of adaptation funds should in the long term be expected to improve the quality of life of forest dependent communities. Such improvements can be facilitated by guaranteed access to resources, improve tenure rights, increase the active participation in policy dialogue, produce legally binding agreements on benefit sharing from the sales of community-led reforestation activities. Furthermore, these development and adaption policies should initiate and maintain the provision of better services and management by the relevant institutions in charge. Adaptation planning and policy in the long term should tackle the whole landscape, promote resilient ecosystem management, and land use zoning schemes (Heller and Zavaleta 2009).

5.6. Windows for adaptive policy and governance

Many African countries including the case study countries have hitherto fallen short of explicitly integrating or mainstreaming climate change into their sectoral policies and development plans although some progress is taking place. In many cases, only the obligatory activities of countries who are signatories to the climate convention have been initiated. These include NAPA and National Communications to the UNFCCC. These key climate change documents make mention of potential adaptation activities related to forestry. Such activities that already exist in many cases may be implemented. What is lacking now is the two-way integration of climate change: not only in the obligatory actions under the UNFCCC but also through the sectors or ministries by whose means the proposed activities are managed and put into operation. This should be supported by statements of policy intent through measures such as laws, regulations, programmes or projects that facilitate implementation activities.

Forest policies and institutions need to encourage adaptation strategies that improve the adaptive capacities of farmers without reducing those of ecosystems or other vulnerable communities. All proposed measures and policies must be acceptable and applicable to the communities. Such forest policies, governance mechanisms and strategies that promote socio-ecological resilience, therefore need to be enhanced. Hybrid governance systems such as community-based forest management will then become crucial. The ‘increasing vulnerability of socio-ecological systems necessitates individual or societal initiatives with the ability to transform interactions between the society and the ecosystem upon which we depend’ (Amitage and Plummer 2010). For example, farmers in Studies II and III have been at the forefront of managing their local forest resources. In some cases, farmers manage the forest in partnership with the state forest institutions (Study IV) that provide extension services and technical support. Although these cases are not perfect, they represent a window for social learning where the activities can be enhanced at the decision making levels and even scaled up where feasible and applicable.

Social learning has the potential to facilitate and foster present day collective community-based forest management in relation to the acceptance of strategies that build the resilience of socio-ecological systems to climate change (Tompkins and Adger 2004). A study on collective and anticipatory learning under climate change uncertainty in Ghana by Tschakert and Dietrich (2010) suggest some areas that are worthy of attention. These include lessons learned from the past climate impacts, monitoring and analysis of trends to anticipate future events, measuring of adaptive capacities, and the design of decision-support tools for adaptation planning. Car (2008) in a study on Ghana stressed the importance of understanding adaptation decision making in terms of how and why people practice particular adaptation activities especially those related to natural resource management. This is in addition to the importance of actors and other structural determinants of adaptation.

The present study provides focuses on researching effective initiatives through the review of current forest policies and governance practices in the light of emerging impacts of climate change. Climate change is a new concept in sustainable forest management practices in all the case study countries. Their forest policies lack clear objectives to address climate change adaptation and mitigation. However, current forestry activities align with forest policy goals and partially support expected climate change adaptation and mitigation actions. However, a major gap is the lack of sufficient support by the forest polices on livelihood-dependent forestry activities notably the exploitation of NTFPs that represent a crucial asset for improving adaptive capacities of vulnerable poor groups. Existing forest governance practices covered in the various case studies can be used as examples of vulnerable community-led forest management to improve adaptive capacities. Policy and governance adjustment need to craft clear policy objectives on climate change adaptation. The objective will then be to build on and enhance existing forest governance practices led by vulnerable poor groups such as smallholder farmers. ‘Shifts from vulnerable poor groups as passive victims of climate change to active agents who shape change’ (sic) (Tschakert and Dietrich 2010); may provide good guidance for policy adjustments on adaptation. Emphasis in the improvement process should also be given to NTFPs through the review of NTFP subsector as already been seen in Burkina Faso.

In all the case study countries, steps to arrest deforestation and maintain forest-based carbon are pushing policy reforms to integrate climate change policy objectives, strategies and programmes in the forest sector. An advanced example is Ghana where the World Bank’s Forest Carbon Partnership Facility already supports necessary institutional reforms in the forest sector. This process in Ghana is further complemented by Ghana’s Voluntary Partnership Agreement (VPA) with the European Union under the Forest Law Enforcement, Governance and Trade (FLEGT).

All these institutional reforms provide opportunities for change and represent policy windows for integrating adaptation issues in forestry. Activities under case studies in Ghana (I and IV) are well mentioned in Ghana's REDD readiness preparation proposal (R-PP) submitted to the World Bank. For example, forest fire protection and plantation activities under the MTS are led by community farmers (Study IV).

Study IV and other case studies demonstrate characteristics of multi-stakeholder deliberations, formal policy review, and continuous learning that represent tools for creating adaptive policies under complex, dynamic and uncertain conditions such as climate change issues (Swanson et al. 2010). In DRC where study V was conducted, the submitted draft of R-PP to UN-REDD by the government demonstrates positive intentions in terms of participation and consultation in addition to the role of the communities in forest management and use of NTFPs as safety nets.

In the case of Sudan (Studies II and III), community-based natural resources management through agroforestry in the gum belt provides one of the best options for REDD. Livelihoods are so intimately attached to tree products (gum arabic) and therefore environmental degradation is a real problem. Despite the popularity/effectiveness of REDD under the auspices of the UNFCCC, it is the AFOLU that is intended to operate at the landscape level that may be better suited to the agroforestry cases of Sudan. It will therefore make sense for forest policy reforms driven by climate change mitigation issues to integrate adaptation issues directly and simultaneously. This will address the dual function of forest for both adaptation and mitigation actions.

6. Conclusions and Recommendations

The present study has demonstrated that forest ecosystems provide services especially provisioning services that represent vital assets for the adaptation of vulnerable poor groups. The need for a resilient and adaptive forest ecosystem is also imperative for the future flow of these services to society. There is therefore a need to strike a balance in terms of how much resources should be extracted while maintaining and managing the health of ecosystems for future productivity and resilience.

Mainstreaming climate change into policy and development plans and activities is still at an early stage and remain challenging for many African governments. The present study presents one of the cost effective ways of addressing climate change through existing governance practices under the existing policies and mechanisms that may seem more practical and feasible for many African governments. The window to integrate climate change is further opened when only minor policy changes are required. The case studies may provide great help to national and local adaptation decision makers to improve adaptive capacities by looking through their own activities.

The scope of the present study was limited to specific forest governance mechanisms that enable vulnerable poor smallholder farmers to use and manage forest resources for adaptation. An additional section dealt with forest policies and management activities that can help forest ecosystems adapt to impacts of climate change. Consequently, the reliability, general application and scaling up of the results must be carefully considered in terms of additional socio-economic, political and governance issues. These issues are related to or include: property rights, tenure systems, forest product markets, the level of application of decentralized forest resource management in addition to the nature and extent of the climate change impacts. Similar examples of the case study activities exist in many other parts of Africa. Nevertheless, they are not very advanced in terms of their implementation and hence realising the potentials of improving the adaptive capacities of vulnerable socio-ecological systems. Some of the above considerations may need further additional studies in the future depending on a case by case evaluation.

In this study it was found that though farmers understood the need to protect the environment and ecosystem, their livelihood needs based on results from this study was their priority. At some point it was a matter of survival. The importance of NTFPs came out as a major resource for farmers' adaptation. NTFPs acted as safety nets in times of shocks and were gathered from all over the landscape ranging from farmlands, forest reserves, forests outside reserves and in bush lands. Some of these provided income for vulnerable poor farmers in greater quantities and with high economic value. No matter the level of subsistence use, farmers laid more emphasis on income generating NTFPs that may enable them meet other livelihood needs. Similarly, many NTFPs with low economic value have not been sufficiently recognised and developed under the forest policy programmes and activities in the case study countries and Africa in general. Most forest rich countries such as DRC and Ghana focus more on timber and its income generating potentials.

The rehabilitation of degraded forest reserves stand a better chance to succeed, if agroforestry concepts that combine tree planting and livelihood needs are implemented. This is especially the case for those lands on which the fast growing short term crops are produced. If well managed and agreements between different parties fulfilled like the case of MTS in study IV, farmers can reap some instant short term benefits in the form of increased crop productivity for both subsistence use and income generation. On dry agricultural lands (Study III), reforestation

activities mainly through agroforestry practices have the potential to rehabilitate degraded lands while providing income to poor farmers through the commercialization of NTFPs.

Evidence found in this study show that the level of income and benefits obtained by vulnerable farmers from reforestation, rehabilitation or NTFPs exploitation is highly dependent on other governance factors related to market, political and policy dynamics. This has great implications for farmers' adaptive capacities in addition to their contributions to implement activities that can help forest ecosystems adapt. Many actors such as market brokers, politicians, ministries in charge of trade, elite groups not often identified within the climate change milieu are increasingly recognised in the present study to have pivotal roles in influencing livelihood outcomes and resources to improve the respective adaptive capacities of vulnerable poor groups. This suggests that the traditional means of identifying adaptation intervention that is solely based and focused on natural resource use and management is recommended to expand and integrate other governance issues that obstruct livelihood improvement. For example, an adaptation intervention in this case may be focused on improving access by farmers to better market prices for selling their NTFPs.

There are indications from this study that the needed forest management practices to help forest adapt to impacts of climate change already exist in some forest policies of many African countries. They are not clearly labelled in the forest policy document as adaptation strategies though. What forest managers in the study countries and Africa in general need is to understand what is needed in terms of adapting forest management practices. They can achieve this by reviewing the consistency of their current activities to the set of proposed practices as demonstrated in study I. Even when these practices exist in African countries, major challenges to the implementation of such practices exist and are related mainly to lack of the needed financial, material and human resources. For example, if the forest policies of Ghana and Burkina Faso were to be fully implemented, they would cover to a greater extent the practices that would help their forests adapt to climate change impacts.

Even at the political level, governments of many African countries understand that adaptation is a priority for Africa. This study focused on forests and adaptation but the huge quantities of money involved in REDD is completely turning the values put on forests and it cannot be ignored. The synergies and tradeoffs between adaptation and mitigation in forestry are highly recommended for future studies.

The success of adaptation process is complex to evaluate especially in the medium and long term. Short term success can be assessed retrospectively to examine how adaptive capacities of vulnerable socio-ecological systems have improved. If the present situation is judged to be better, then the medium and long term success can be built upon the foundations of the present situation.

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