NON-TIMBER FOREST PRODUCTS FOR CLIMATE CHANGE ADAPTATION AROUND IYONDO FOREST RESERVE IN KILOMBERO DISTRICT, TANZANIA

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ABSTRACT

The aim of this thesis was to enhance the understanding of the role of Non-Timber Forest Products (NTFPs) in climate change adaptation through studying households adjacent and distant to Iyondo Forest Reserve (IFR) in Kilombero District, Tanzania. Apparently, Kilombero District is prone to diverse climatic stresses; and the role of NTFPs in the way that households adapt and achieve livelihood security in the face of climate stressors is neither well known nor documented. The study aimed at addressing this need through use of sustainable livelihood framework. Data were collected using socio-economic appraisal, forest inventory and review of secondary information. Both qualitative and quantitative analyses were undertaken. The multinomial logistic regression analysis was used to analyze the socio-economic factors influencing adoption of developed adaptation strategies. Findings showed that both households adjacent and distant perceived prevalence of changing climate in terms of dry spells, floods, heavy rains and extreme heat. Three NTFPs namely: firewood, medicinal plants and thatch grasses were identified to be of priority. The number of stems and seedlings per hectare of firewood and medicinal trees species in IFR was relatively high implying availability and active natural recruitment. The economic value of the priority NTFPs, at a discounting rate of 10% was TZS 31 971 508 412.24. The households had developed local adaptation strategies that include: use of NTFPs, as well as farm and non-farm strategies, such as crop diversification, changing cropping calendar, adopting modern farming techniques, livestock rearing and fishing. Inferential statistics showed that household size, residential period, land ownership and household income were the socio-economic variables that influenced adoption of existing local adaptation strategies positively and significantly at 5% probability level. The study concluded that NTFPs were not only used for subsistence but also for different types of livelihood capitals. They are closely linked to people's portfolio of wider strategies that were often used for trade and gaining financial capital. Findings suggested that policies aimed at supporting rural adaptive capacity need to address the rules and social factors that impede access and support the way NTFPs contribute to various types of livelihood capitals.

DECLARATION

I, **CHELESTINO PETER BALAMA**, do hereby declare to the Senate of Sokoine University of Agriculture that this dissertation is my own original work done within the period of registration and that it has neither been submitted nor being concurrently submitted in any other institution.

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"TO GOD BE THE GLORY''

DEDICATION

To my Father, the Late Mzee Peter Vangilichuma Balama and My Mother, Benadetha Daudi Kwavava who laid down the foundation of my education through dedication of their financial and social capitals.

And,

To my beloved wife, Christina Paschal Tewele, daughters Cecilia and Catherine who withstood my absence and long working hours. May the Almighty God bless you all.

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LIST OF ABBREVIATIONS AND ACRONYMS

ANSAB	Asia Network for Sustainable Agriculture and Bio-resources
BMZ	German Federal Ministry for Economic Cooperation and Development
CCIAM	Climate Change Impacts Adaptation and Mitigation
Dbh	Diameter at Breast Height
DFID	Department for International Development
DRC	Democratic Republic of Congo
EAMCEF	Eastern Arc Mountains Conservation Endowment Fund
FAO	Food and Agriculture Organisation of the United Nations
FGDs	Focus Group Discussions
GPS	Global Positioning System
Ha	Hectare
HHs	Households
IFR	Iyondo Forest Reserve
IPCC	Intergovernmental Panel on Climate Change
JFM	Joint Forest Management
KIVEDO	Kilombero Valley and Development Organization
KNR	Kilombero Nature Reserve
KPL	Kilombero Plantation Limited
KVFRS	Kilombero Valley Floodplain Ramsar Site
MFIs	Micro Financial Institutions
NAPA	National Adaptation Programme of Action
NTFPs	Non-Timber Forest Products
PFM	Participatory Forest Management

PRA	Participatory Rural Appraisal
RYMV	Rice Yellow Mottle Virus
REDD+	Reduced Emissions from Deforestation and Forest Degradation plus
SACCOS	Savings and Credit Cooperative Societies
SIDO	Small Industries Development Organization
SNAL	Sokoine National Agriculture Library
SPSS	Statistical Package for Social Sciences
SUA	Sokoine University of Agriculture
TAZARA	Tanzania-Zambia Railway Authority
TAFORI	Tanzania Forestry Research Institute
TB	*Tubercle bacillus*
TFS	Tanzania Forest Services
TMA	Tanzania Meteorological Agency
TZS	Tanzanian Shillings
UN	United Nations
UNMB	Norwegian University of Life Sciences
UNFCCC	United Nations Framework Conversion on Climate Change
URT	United Republic of Tanzania
USD	United States Dollar
VEC	Village Environmental Committee
VETA	Vocational Educational and Training Authority
VICOBA	Village Community Banks
χ^2	Chi square test
YOSEFO	Youth Self Employment Foundation

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background

The aim of this thesis is to enhance the understanding of the role of Non-Timber Forest Products (NTFPs) in climate change adaptation through studying households adjacent and distant to Iyondo Forest Reserve (IFR) in Kilombero District, Tanzania. The motivation of the thesis is a concern on how households use NTFPs and other diverse strategies to adapt and achieve livelihood security in the face of climate stressors. Forests provide a large variety of products including both timber and Non–Timber Forest Products (NTFPs), and offer diverse environmental services (Perez *et al*., 1997). According to FAO (1999), NTFPs encompass “all biological materials other than timber, which are extracted from forests, other wooded lands and trees outside forests for human use”. Examples of NTFPs are fruits, mushrooms, roots, leaves, bark, fibre, grasses, seeds, nuts, and fodder. Others are latex, bamboo, rattan, honey, resins, gums, flowers, edible insects, building poles, firewood, charcoal, and bush/wild meet.

Throughout the world, NTFPs contribute to subsistence, employment and cash incomes of many people in need (Shackleton *et al.,* 2011). Of particular importance to the field of adaptation to climate change, is the way in which NTFPs provide livelihood benefits and help rural populations manage adverse events such as sudden changes in the economic, social or bio-physical environments in which households exist and function (Augustino, 2006; Assan and Kumar, 2009; Nkem *et al*., 2010; Gachathi and Eriksen, 2011; Schaafsma *et al.,* 2012). The relationship between NTFPs and climate change is dynamic. Climate change is a concern to livelihoods, and also affects both supply and demand of NTFPs. Climate change is a key challenge that may influence sustainable livelihoods and economic development, particularly for developing countries like Tanzania (URT, 2009a).

This influence of climate change on rural livelihoods and natural resources is diverse and fundamental. Climate change has been reported to have significant effects on rain-fed agriculture and food production (Ziervogel and Calder, 2003; Eriksen *et al.*, 2005; Eriksen and Lind, 2009; Olsson *et al.,* 2014). Tanzania has also been severely affected since it depends primarily on rain-fed agriculture (Eriksen *et al.,* 2005; Shemsanga *et al.,* 2010; Ahmed *et al*., 2011), with only 1.6% of arable land having irrigation facilities (URT, 2010a). Much of the cropland is rain-fed and is therefore vulnerable to climate change that is characterized by drought and floods including season unpredictability that frequently cause crop failure. In general African countries including Tanzania are vulnerable to climate change effects due to her low human adaptive capacity to anticipated increases in extreme events, heavy reliance on rain-fed agriculture, lack of economic and technological resources, insufficient safety nets and educational progress (Somorin, 2010).

The implications are particularly serious for the poorest and most vulnerable social groups especially households adjacent to forests. Rural populations with low income who also rely on ecosystem services are more vulnerable to the adverse effects of climate change, which contributes to the loss of their natural resource base (Niang *et al.,* 2014; Olsson *et al.,* 2014). Adaptation through reducing vulnerability is therefore one of the approaches considered likely to reduce the impacts of long-term climate changes. Such adaptation policy interventions target the development and enhancement of local strategies to moderate and cope with the environmental variability (Adger *et al*., 2007; Vogel *et al*., 2007). Importantly, it has been argued by Ahenkan and Boon (2010) and

Nkem *et al*. (2010) that sustainable utilization of NTFPs could be among the effective climate change adaptation strategies in Africa. Several climate change related policies and programmes have focused on NTFPs. According to UN (2009), NTFPs are one of the co-benefits of REDD+ (Reduced Emissions from Deforestation and Forest Degradation plus). Through its implementation, communities will gain more benefits of ecosystem services, especially through creation of sustainable NTFPs based enterprises (URT, 2010b). Giam *et al*. (2010) concluded that REDD+ mechanism might allow communities in developing countries with high conservation needs of their natural resources to increase economic revenue, prevent habitat loss, while mitigating carbon emissions and effects of climate change. However, the Fifth Assessment Report of the IPCC (Olsson *et al*., 2014) argued about latent negative impacts of REDD+, which might include: exclusion of local people from forest use, loss of local ownership in documenting the state of forests due to external monitoring and verification mechanisms, and unevenly distribution of benefit.

There are gaps, however, in knowledge of the role that NTFPs play in adaptation to climate change to enhance adaptive capacity of households or populations. It is against this background that, this thesis explored this gap, focusing on the role of sustainable utilization of NTFPs in strengthening adaptive capacity in the context of climate change. The thesis focused in particular on households in Kilombero District, Tanzania, who have been selected as a case study because their main livelihoods are vulnerable to climate induced stresses including floods, dry spells, pest and diseases and extreme heat.

1.2 Problem Statement and Justification

1.2.1 Problem statement

Households in Kilombero District, which is the case study location, rely on agriculture and forest resources for their livelihoods. Like in other parts of Tanzania, the majority of people in Kilombero District depend on rain-fed agriculture as their main source of livelihoods (Shemsanga *et al.,* 2010; Ahmed *et al*., 2011), the sustainability of which is threatened by socio-environmental processes such as climate change (URT, 2012a). Studies suggest that many households in Kilombero District are vulnerable to climate related shocks and stressors. For example, Chamwali (2000), Starkey *et al*. (2002) and Harrison (2006) have shown that Kilombero District in Tanzania is prone to frequent floods, dry spells during rainy season, extreme heat and some other climate stresses, which have adverse effects to the livelihoods of the communities. According to the Tanzania National Climate Change Strategy (URT, 2012a) floods, landslides and associated waterborne diseases are on the increase in Kilombero District, whereby older people, women and children are most impacted.

The Fifth Assessment Report of the IPCC (Smith *et al.*, 2014a) describes how older people are usually at greater risk from storms, floods, heat waves, and other extreme events partly because they tend to be less mobile than younger adults, more likely live alone in some cultures and thus find more difficult to avoid hazardous situations. During such times of stresses, the most important coping strategy for households involves gathering of NTFPs such as wild mushrooms, firewood, wild fruits, thatch grasses, medicinal plants, bush meat, building poles to mention a few. This reliance on forest resources is often greater considering that forests also support local industries that produce wood products (Nkem *et al*., 2010).

The role of NTFPs to assist households to cope and or adapt to the adverse effects of climate change for livelihood security in Kilombero District is neither well known nor documented. Most of the adaptation studies in East Africa have focused on agricultural production or livelihoods (Orindi and Eriksen, 2005; Verchot *et al.,* 2007; Naess, 2008; Lema and Majule, 2009; Lyimo and Kangalawe, 2010; Mongi *et al*., 2010), yet there is increasing evidence that households engage in many activities beyond agricultural production and that forest products are particularly important in how they manage socio-environmental stresses. Schaafsma *et al.* (2012) observed that, collection of NTFPs around the Eastern Arc Mountain forests of Tanzania provides variety of products used for domestic consumption, as well as sources of complimentary cash income and a safety net for people when agricultural yields are low. According to Osman-Elasha *et al.* (2011) collection and sale of NTFPs provide employment during slack periods of the agricultural cycle and provide an income buffer against climate risk and household emergency. The Tanzania National Adaptation Programme of Action (NAPA) has indicated NTFPs to be among the potential resources for climate change adaptation (URT, 2007). Studies elsewhere in Africa (Vedeld *et al*., 2007; Mamo *et al*., 2007; Babulo *et al*., 2009) indicated that, forest income in many developing countries acts as insurance in periods of unstable economic shocks, that is unexpected income shortfalls or cash needs.

Frequent floods, dry spells and heat stress are among the climate change stresses that contribute to food insecurity due to reduced crop yields, thus increasing vulnerability of the people (Common and Stagl, 2005; Pittock, 2009). Other stresses and shocks related to climate include decreased water availability for household consumption; increase in human exposure to vector-borne and water-borne diseases; and pests. It has been urged that multiple stressors like deprivations, market shifts, conflict, insecurity, and loss of access to resources to exacerbate the vulnerability of rural households to the adverse effects of climate change (Niang *et al.,* 2014; Olsson *et al.,* 2014). Poor population groups might not have the financial and technical capacities to develop resilience or adaptation to climate change effects (Ruettinger, 2012). Similarly, other livelihood resources that are sensitive to climate change effects are the forest resources due to prolonged dry spells, wild fires as well as pest attack. The IPCC Fifth Assessment Report (Settele *et al.,* 2014) revealed forest resources to be vulnerable to both direct effects of climate change including high temperatures, drought, and windstorms; as well as indirect which include increased risk of fires and pest and disease outbreaks. It is against this background that, a study to investigate the role of NTFPs resources for adaptation to climate change adverse effects by households adjacent and distant to IFR in Kilombero District was carried out.

1.2.2 Justification

The study has generated empirical information on NTFPs and climate change adaptation in low altitude areas that can inform different national existing strategies and policies for example the National Forest Policy (Under review), National REDD+ Strategy and Action Plan (2013), National Climate Change Strategy (2013) and NAPA (2007) within the forestry and natural resources related sectors in Tanzania. Ferreira *et al*. (2012) argued that sustainable management of NTFPs plays two potential roles in REDD+. Firstly, it helps to reduce NTFPs extraction that contributes to forest degradation and associated emission. Secondly, it enables sustainable exploitation of NTFPs that can contribute to reducing degradation and deforestation caused by other factors, through: (a) increasing value of the forests and thereby reducing pressure on them, and (b) providing alternative sources of income to activities that deplete forest carbon stock. However, the potential for increasing the sustainability of NTFPs use depends on the products extracted and the characteristics of the species and the forests (Ferreira *et al*., 2012). For example harvesting of dead wood, fruits, seeds and mushrooms has been pointed out to have the high potential for sustainability.

The study also forms basis for policy makers and other stakeholders to formulate and or strengthen the existing adaptation strategies within the natural resources sector in Tanzania and other places in Africa where the current global efforts to combat climate change effects through the forest sectors are advocated. Similarly, sustainable adaptation through use of NTFPs is of absolute importance because studies have indicated that natural forests are more resilient to climate change impacts than monoculture plantations (Ravindranath, 2007; Smith *et al*., 2014b). Furthermore, Nkem *et al*. (2007) revealed that natural forests are less sensitive to climate change effects compared to agricultural crops.

1.3 Objectives

1.3.1 Overall objective

The overall objective of this study was to enhance the understanding of the role of NTFPs in climate change adaptation to households adjacent and those distant to Iyondo Forest Reserve in Kilombero District, Tanzania.

1.3.2 Specific objectives

The specific objectives of the study were:

i. To study the households' perceptions on effects of their livelihoods on changing climatic conditions in the study areas;
ii. To study the availability and use of priority NTFPs under the current change in climate in the study areas;
iii. To improve understanding on the economic value of priority NTFPs in the study areas under the changing climatic conditions;

iv. To improve understanding on the current roles of selected priority NTFPs and other adaptation strategies used by households to cope with effects of climate change in the study areas.

1.3.3 Research questions

The study was guided by the following research questions:

(i) How do households perceive climate change and its effects to livelihood security?

(ii) What are NTFPs status and their use under changing climatic conditions for households' livelihood adaptation?

(iii) How economically valuable are the NTFPs in enabling households' livelihood adaptation?

(iv) How are the priority NTFPs and other strategies used to manage adverse effects of changing climate?

(v) How are institutions influencing households' access to priority NTFPs?

1.4 Analytical Framework for Enhancing Understanding of the Role of NTFPs in Climate Change Adaptation

1.4.1 Conceptual framework

A conceptual framework describes relations between the main concepts a research project work, based on selected, prevailing theories and associated empirical works (Angelsen *et al.,* 2011). The conceptual framework for this study is based on Sustainable Livelihood (SL) framework approach (DFID, 2001). The framework (Fig. 1) shows how people might be able to manage climate change vulnerability context through livelihood adaptation strategies. In this study, the framework has been applied to the case of households. Firstly, the vulnerability context refers to the external environment in which the households live, as well as their perspectives on that environment (DFID, 2001). Households' livelihoods and assets are affected by critical shocks and stresses - factors over which they have very little or no control. Shocks refers to sudden events that can destroy the assets of the people, such as droughts, floods, extreme weather events, retrenchment and death of economically active member, civil conflicts (Chambers and Conway, 1992). Besides the shocks, stresses such as long-term food insecurity and limited access to essential services such as health or water supplies as well as degraded resource also hinder households' adaptive capacity (Ellis, 2000). Overall, the complex influence of the vulnerability context puts pressure on the livelihoods of the households in such a manner that they are unable to earn enough to cope with the stresses.

Secondly, possession of and access to different types of assets or resources generally termed capitals are crucial for the livelihoods of the poor. Since SL framework approaches are people-oriented, it is important to understand the status and strengths of people's assets and how they convert these into positive livelihood outcomes (DFID, 2001). The SL framework is based on the assumption that people require a range of assets to achieve a positive livelihood outcome, and it is more applicable in the case of the poor. In the SL framework, the capital is represented by a pentagon comprising five types of capitals:

Human capital: The skills, knowledge, ability to labour and good health that together enable people to pursue different livelihoods strategies and achieve their livelihood objectives.

Social capital: The social resources upon which people draw in pursuit of their livelihood objectives, including social networks, entertainment, sports, membership of formalized groups and relationships of trust.

Natural capital: The natural resource stocks from which resource flows and services useful for livelihoods are derived. Examples of resource stocks and services derived from them include land, forests, marine/wild resources, water, and biodiversity, among others.
Physical capital: The basic infrastructure and producer goods (such as equipment, schools, housing, hospitals, water and sanitation, roads, transport, communications) needed to support livelihoods.
Financial capital: The financial resources that people use to achieve their livelihood objectives (for example, earned cash income, savings, and credit facilities).

These assets have highly complex relationships with other components of the framework. To focus on vulnerability and assets, the later can be destroyed or created by shocks and stresses. Considering the influence of structure and processes on assets, for example, government policies, legislation, and other institutions can create infrastructures, promote technology, define property rights, improve access to NTFPs-market information, and determine access to the assets.

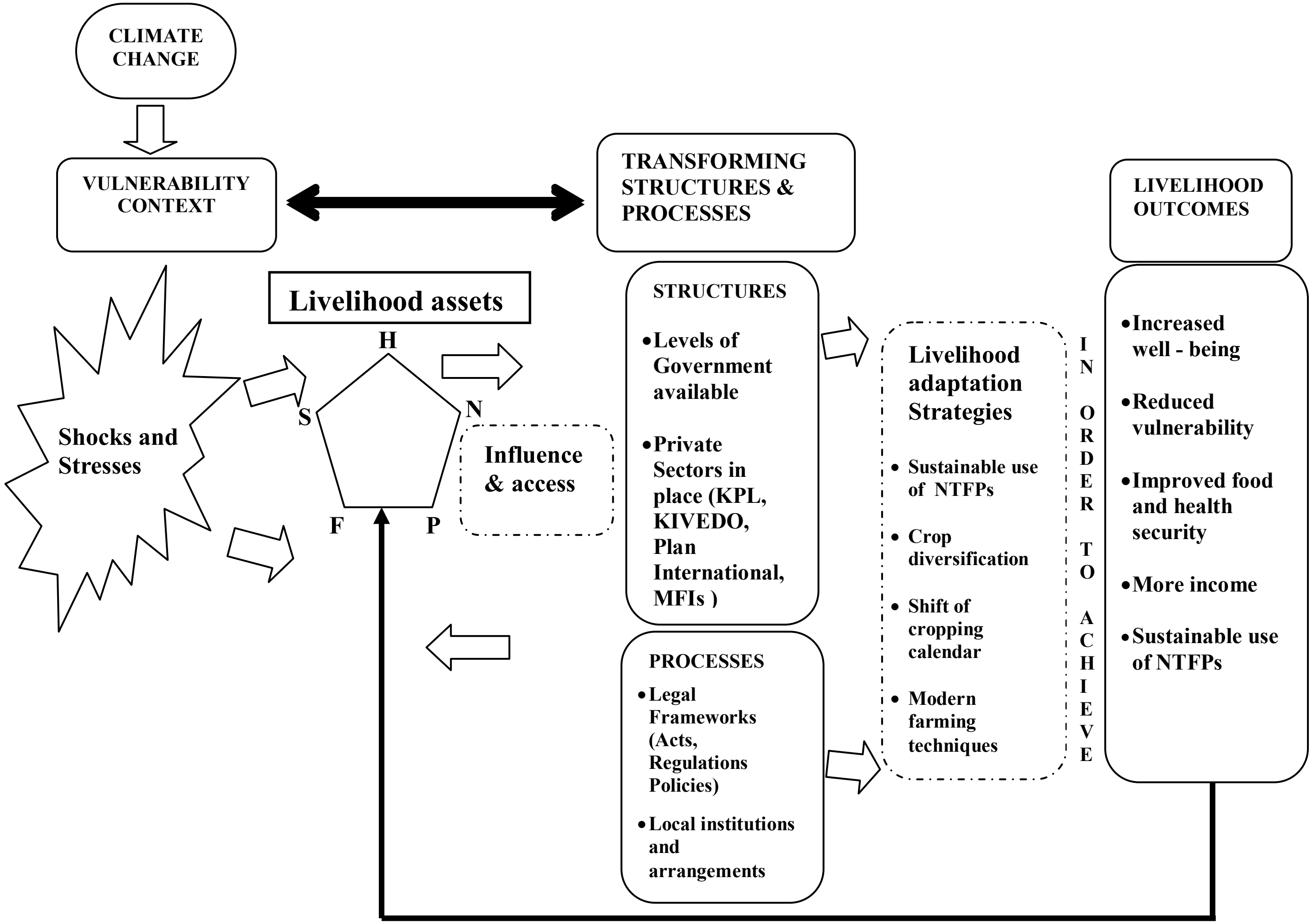
Thirdly, institutions, both formal (the government, organizations, policies and legislation) and informal such as cultural norms and customs can play a vital role in shaping households' livelihoods (DFID, 2001). They determine access to capitals, strategies, and decision-making capability; identify the extent and sources of influence on assets; and explore terms of exchange between different types of capital and their returns to any given livelihood strategy (DFID, 2001). Transforming structures and processes have a direct feedback to the vulnerability context (DFID, 2001). Institutions including political structures and policies define households' livelihood strategies and have a direct impact on livelihood outcomes. Structures that comprise public and private organizations and agencies, such as legislative bodies, executive agencies, NGOs and civil society, are important as they affect and monitor the processes. To achieve positive livelihood outcomes there are several options: building organizations that will represent the poor, promoting reforms, expanding scope of opportunities, and supporting joint forums for decision-making and action (DFID, 2001). Likewise, processes such as policies and legislations are very important for every aspect of livelihood. Need to pay attention to cultural norms is also important.

Fourthly, livelihood strategies can be seen as the combination of activities that households engage in with the purpose of attaining their livelihood goals. The strategies are diverse; vary in accordance with geographical areas and the level of household involvement in different livelihood activities. Peoples' access to different assets is influential in determining the livelihood strategies they use. Further, depending on the shocks or stresses and the combination of household capitals that people have, their livelihood strategies change because of positive structure and process transformations such that better livelihoods are the outcomes.

Fifthly, improved livelihood outcome is the goal of the SL framework's development interventions. The outcomes are the outputs or achievements that accrue from the households' livelihood strategies. It is also important to observe and investigate the richness of the potential livelihood undertaken by the people. Identifying the compelling situations and underlying constraints in a particular livelihood outcome is crucial for future interventions. There are several types of livelihood outcomes, including improved well-being, more income, reduced vulnerability, improved food security, and more sustainable use of the natural resource base (DFID, 2001) including the NTFPs.

1.4.2 Framework operationalization

The SL framework (Fig. 1) described under section 1.4.1 was used to operationalize the research questions in the empirical investigation in chapter 4. In chapter five, the contribution of the study to this framework and current theories is described. The framework has been operationalized for this study as follows: in the first place, it is assumed that households adjacent to forest are affected by climate change through shocks and stresses. On the other hand, the presence of NTFPs as part of livelihood assets could enable households cope with and adapt to shocks and stresses through subsistence use and cash income. NTFPs contribute to livelihood capital assets through subsistence use and cash income. In most cases resources availability has been mediated by the transforming structures and available processes that influence and govern access to the livelihood resources. NTFPs could form part of livelihood adaptation, which is enhanced by the set structures and processes. In this study, transforming structures that were revealed to enhance adaptive capacity included Kilombero district authority and Village governments, as well as private sectors mainly the Kilombero Plantation Ltd, Plan International, Kilombero Valley and Development Organization (KIVEDO) and several existing micro financial institutions. On the other hand, existing legal frameworks and local institutions affected accessibility and collection of priority NTFPs. Sustainable utilization of NTFPs could positively contribute in achieving livelihood adaptation outcomes that will mitigate the current climate change and variability effects. The achieved livelihood outcomes will then reduce climate change vulnerability through improved well-being, increased income, food and health security as well as sustainable utilization of NTFPs and forest resources as a whole.



Source: DFID (2001), Adopted and modified

Figure 1: Conceptual framework on Sustainable Livelihood Approach

Key: F=financial capital; H=human capital; N=natural capital; P=physical capital; S=social capital;
KPL = Kilombero Plantation Limited; KIVEDO = Kilombero Valley and Development Organization; MFIs = Micro-financial institutions

The SL framework is also useful in describing components of incremental adaptation[1]at a local level though it may also point to what fundamental attributes of structures and systems must be transformed in order for more climate resilient pathways to be achieved, including reduced poverty and inequality (Olsson *et al.,* 2014). While being aware of the importance of these aspects for understanding local vulnerability dynamics, and that forests undoubtedly play a role in people's efforts to secure such aspects of well-being, this study nevertheless focuses specifically on the relationship between NTFPs use and household ability to secure livelihoods in the face of climatic shocks and other stressors.

1.4.3 Link between research questions and the conceptual framework

The research objectives of this study were operationalized through four research questions as indicated under Section 1.3.3. The research questions are linked to the SL framework that was adopted as a central tool for analysis and discussion. The SL framework indicated how livelihoods of the households are affected by the shocks and stresses, which are due to current varying climatic condition and global climate change. The first research question focused on understanding how households perceive climate change and its effects on livelihood security. This information was important to understand how these people are managing the perceived shocks and stresses. The second research question focused on livelihoods assets and transforming structures and processes, which are among the components of the SL framework. NTFPs, which are part of the natural capital asset, are currently important for livelihood adaptation to offset the adverse effects of the varying climate including global climate change. Therefore, this research question was geared towards understanding the NTFPs status and their use under the changing climate for households' livelihood adaptation. However the existing transforming structures and

[1] Adaptation actions where the central aim is to maintain the essence and integrity of a system or process at a given scale (IPCC, 2014).

processes influence access and sustainable utilization of the NTFPs. Understanding the status and use of the NTFPs was also important in order for policy makers to plan for sustainable collection of the products under current climate shocks and stresses.

The third research question links between livelihood assets and outcomes in the SL framework. This research question focused on identifying the economic value of the NTFPs to enable households' livelihood adaptation. The main goal of this research question was to see how the improved income is understood among the households. The fourth research question bridges between livelihood assets and the adaptation strategies. The research question focused on understanding how the priority NTFPs and other strategies are used to manage adverse effects of changing climate. The research question brings together diverse strategies including NTFPs, crop diversification, changing cropping calendar, adopting modern farming techniques, livestock rearing, fishing and petty business which are important to households in managing adverse effects of changing climatic conditions including climate change. The final research question focused on how the existing transforming structures and processes (rules and regulations) influence access to the livelihood assets in the SL framework. In the context of this study, the research question provided interaction between managing vulnerability and biodiversity conservation.

1.5 Organization of the Thesis and Preview of Findings

The thesis consists of five chapters. The present chapter has discussed the background and justification to the research and outlined its objectives. Chapter two presents the state of knowledge on the subject matter including definition of terms and concepts, theories on adaptation to climate change, vulnerability and livelihoods. The chapter also reviews effects of climate change on dynamics of vegetation, as well as valuation of priority

NTFPs. Chapter three presents methodology used by describing the study area, different methods used in data collection as well as its analysis. The study findings are presented and discussed in chapter four, in the light of other related works within the NTFPs and climate change adaptation context. The study finds that climate change has already affected the livelihood of households adjacent and distant to IFR in terms of increasing dry spells, floods, heavy rains and extreme heat. To manage adverse effects of changing climatic conditions, households adjacent and distant to IFR have developed local diverse strategies including increased reliance on use of NTFPs, crop diversification, changing cropping calendar, adopting modern farming techniques, livestock rearing, fishing and petty business. The key arguments are that sustainable utilization and development of priority NTFPs including value addition could enhance households' adaptive capacity to adverse effects of present and future changing climatic conditions including climate change. Chapter five presents general conclusions and implications for research and policy in the light of the results of the work as a whole. The study has revealed that NTFPs are used for different types of livelihood capital assets, often for trade to gain financial capital additional to household subsistence. However, the rules governing the forest resources access often impede people's adaptive capacity, as collection of NTFPs is currently highly restricted. Findings suggest that policies aimed at supporting rural adaptive capacity need to address the rules and social factors that impede access. Further, rules need also to support the way that NTFPs contribute to various types of livelihood capitals and how these resources relate to other strategies. The chapter also suggests further investigations to promote sustainable utilization of NTFPs to enhance adaptive capacity of the households in Tanzania and elsewhere within Africa. Lastly, a need for ecological studies to verify if NTFPs have been affected by climate change is also recommended.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Overview

This chapter reviews literature related to role of Non-Timber Forest Products (NTFPs) in supporting adaptation to adverse effects of climate change to households. NTFPs are not only important in dry land areas where they form alternative sources of livelihood as revealed by FAO (1999) but also to households in humid areas like of Kilombero District. Studies (e.g. Nkem *et al*., 2010; Gachathi and Eriksen, 2011; Schaafsma *et al.,* 2012) have indicated that NTFPs provide livelihood benefits to people in rural areas by assisting them to manage adverse events. The chapter begins by presenting the state of knowledge through defining terms and concepts within climate change, vulnerability and adaptation. It further explains the way the study approaches nature-society relations, reviews some theories on adaptation to climate change, effects of climate change on livelihoods and ways NTFPs contribute to households' livelihoods. Review on climate change adaptation as a social and political process has been done with emphases on climate change adaptation as a social transformation, political process and gender dimension. The chapter also reviewed past studies regarding to the effects of climate change on dynamics of vegetation, as well as valuation of NTFPs.

2.2 Terms and Concepts Used

2.2.1 Climate change

According to IPCC (2014) climate change refers to ‘‘a change in the state of the climate that can be identified (for example, by using statistical tests) by changes in the mean and/or the variability of its properties and that persists for an extended period, typically decades or longer''. It sometimes refers to any change in climate over time, whether due to natural variability or because of human activity. Climate change may also be due to natural internal processes or external forces such as modulations of the solar cycles, volcanic eruptions, and persistent anthropogenic changes in the composition of the atmosphere or in land use (IPCC, 2014).

This usage differs from that in the United Nations Framework Convention on Climate Change (UNFCCC) in its Article 1, which defines climate change as: ''a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods'' (UNFCCC, 1992). The UNFCCC thus makes a distinction between climate change attributable to human activities altering the atmospheric composition, and climate variability attributable to natural causes. This study adopts the IPCC definition because it captures both natural variability and anthropogenic activities as the main causes of climate change.

2.2.2 Livelihood

Livelihood is defined as the means, ''activities, entitlements and assets by which people make lives'' (Chambers and Conway, 1992). According to Ellis (2000) a livelihood comprises the assets (natural, human, physical, financial and social capital), and the access to these (mediated by institutions and social relations) that together determine the living gained by the individual or household. A livelihood is sustainable when it can cope with and recover from stresses and shocks maintain or enhance its capabilities and assets, while not undermining the natural resource base (Chambers and Conway, 1992). The term sustainable livelihood thus implies that livelihoods are stable, durable, resilient and robust in the face of both external shocks and internal stresses (Scoones, 2009).

The construction of a livelihood is an on-going process, as it does not remain always the same from one season to the next, or from one year to the next, as because assets can be built up, eroded, or instantaneously destroyed for example by floods, cyclone, pests and diseases (Ellis, 2000). Earlier Scoones (1998) pointed out that, livelihood strategies are related to the level of risk and uncertainty experienced by resource users, whose majority of them have low possessions of natural resources which are also frequently subject to drought, flooding or other hazards. This study examined livelihood adjustments in the face of climate change.

2.2.3 Vulnerability

According to IPCC (2014), vulnerability refers to "the propensity or predisposition to be adversely affected". According to Schipper and Burton (2009) vulnerability is ''a socially constructed phenomenon influenced by institutional and economic dynamics''. Institutional dynamics may include changes in government policies that govern equitable distribution of benefits from different resources including natural, healthcare and food security. While, economic dynamics mainly involves market shifts of agricultural products as well as instability of local currencies compared to foreign ones, which have influence on imported products.

In the context of this study, vulnerability is understood as ''the propensity or predisposition to be adversely affected by climate change, including climate variability. The study puts in action the definition by IPCC (2014) with reference to climate change adverse effects. The definition of vulnerability by Schipper and Burton (2009) is also applied to this study because the forest that the households are depending on for livelihoods has undergone institutional changes particularly on the policies governing the forest resources. The Iyondo Forest Reserve is adjacent to households who depend on NTFPs for their livelihoods is now changed to nature reserve called Kilombero Nature Reserve in which its core management objective is total protection. This now bring another stress to the households apart from climate stresses.

According to Schipper and Burton (2009) vulnerability of a system is a function of exposure, its sensitivity, and adaptive capacity (Metzgar *et al.*, 2006; Schipper, and Burton, 2009; Turner, 2010; IPCC, 2014). IPCC (2014) explained exposure as the people; livelihoods; environmental services and resources; infrastructure; economic, social, or cultural assets in places that could be adversely affected. Adger (2006) defined exposure as the degree, duration and/ or extent in which the system or asset is in contact with, or subject to the perturbation. Sensitivity entails the degree to which a system is modified by the stressors (Adger, 2006) and a function of human conditions and natural capital. The IPCC (2014) defined sensitivity as the degree to which a system is affected, either adversely or beneficially, by climate related stimuli. While Gallopin (2006) expressed sensitivity as the degree to which the system is modified or affected by an internal or external disturbance or set of disturbances. Sensitivity in the context of this study is understood through the combinations of the concepts mentioned as far as the livelihood capital assets of the households are modified by different stressors.

On the other hand, adaptive capacity refers to the ability of a system to adjust to climate change (including climate variability and extremes) to moderate potential damages, to take advantage of opportunities, or to cope with the consequences (Smit and Wendel, 2006; Adger *et al.,* 2007) and has three components that is, awareness, ability and action. Adaptive capacity is influenced by economic development and technology, and social factors such as human capital and governance structures (Adger *et al*., 2007).

It is anticipated that the adaptive capacity of the households in the study area could be enhanced through use of the existing forest resources particularly NTFPs as far as other livelihoods resources including agriculture are adversely affected by climate change.

2.2.4 Adaptation

IPCC (2014) defined climate change adaptation as ‘‘a process of adjustment to actual or expected climate and its effects, in order to moderate harm or exploit beneficial opportunities’’. Moser (2010) and Regmi *et al*. (2010) mentioned that some of the adaptive actions might turn out maladaptive. It is therefore important that adaptation actions are carefully planned and handled in order that adaptation strategies are successful in lessening harm. According to Moser (2010), adaptation strategies can range from short-term to long-term, aim to meet more than climate change goals alone, and may or may not succeed in moderating harm or exploiting beneficial opportunities. Coping can be distinguished from adaptation as it refers to the use of existing resources to achieve desired goals during and immediately after climate-induced hazards (Regmi *et al*., 2010).

In other words, coping is a short-term strategy that is applied immediately after events in order to moderate harm. In a long run, some coping strategies may then be developed to become adaptation strategies. In the context of this study, climate change adaptation is understood as an approach in which households adjust to climate change effects, to moderate potential damages, to take advantage of opportunities in order to enhance resilience and adaptive capacity to observed or expected climate variability and its effects. Various policies and planned interventions can support such local level adaptation. Different theories of adaptation are reviewed in detail in the next section.

Climate change is one of the persistent stresses that individuals and communities have to adapt to (Ziervogel and Calder, 2003). The growing evidence of anthropogenic climate change demands that adaptation options, adaptive capacity and ways to reduce risk be prioritized (Kelly and Adger, 2000; Smit and Wandel (2006). Livelihood resources particularly in Kilombero District are subject to multiple shocks and stress that can increase household vulnerability (URT, 2012a). According to Chambers and Conway (1992), ‘‘shocks are sudden events which undermine household livelihoods’’. These include drought, floods, extreme weather events, retrenchment and death of economically active member. Meanwhile stresses are on-going pressures, which face household and individuals. They include: long-term food insecurity and limited access to essential services such as health or water supplies as well as degraded resource base (Ellis, 2000). Frequent incidences of shocks and stresses reduce adaptive capacity of households, as most of their economic activities are sensitive to changes in climatic conditions.

2.3 Relationship between Nature and Society

Nature in the broadest sense is the natural, physical or material world or universe. It also refers to the phenomena of the physical world, and to life in general. Vining *et al*. (2008) described nature as something that is “out there” without human involvement. On the other hand, human society is a group of people involved in persistent social interaction, or a large social grouping sharing the same geographical or social territory, typically subject to the same political authority and dominant cultural expectations. Human societies are characterized by patterns of relationships (social relations) between individuals who share a distinctive culture and institutions; a given society may be described as the sum total of such relationships among its constituent members (Vining and Merrick, 2008).

In the context of this study, nature refers to existence of forest resources that are the source of NTFPs among other products with human society interaction.

Watts (2000) expressed relationship between nature and society as a complex association that goes through analysis of what one might call the forms of access and control over resources and their implications for environmental health and sustainable livelihoods. In this context, Watts (2000) arguments are in line with the current study as it focuses on the existing relationship between nature and society when increasing their adaptive capacity to climate change through sustainable use of the NTFPs. Land being part of the nature, Blaikie and Brookfield (1987) revealed existence of relationship between land degradation and society which was socially and physically related. With such considerations, it is sufficient to establish land degradation as a problem of both social and physical significance.

On the other hand, nature is overwhelmed by an unprecedented combination of climate change related events, and land-use change, pollution, siltation and over-exploitation of various natural resources including forests and water (Pittock, 2009). All social groups feel the impacts of climate change on natural resources like water. However, where water sources are depleted or quality compromised, women and children are the most affected (Olsson *et al.,* 2014). Robbins (2012) argued that the relationship between nature and society further explains potential environmental conflict especially in terms of struggles over "knowledge, power, and practice" and "politics, justice and governance". In the same vein, Homer-Dixon (1994) explained that decreasing supply of physically controllable environmental resources, such as clean water and good agricultural land, would provoke interstate conflicts or resources wars. However, others have challenged the view that conflict over resources are driven by 'environmental scarcity' but argue that they are rather due to historical and policy context (Benjaminsen *et al.,* 2009). The same authors found that a farmer–herder violence that took place in Kilosa District, Tanzania was not only driven by rising human population but also due to modern policies marginalizing pastoralists, issues of governance and corruption. This situation could be experienced in Kilombero Districts under the current study, as there are conflicts between pastoralists and farmers due to shortage of land. The current study noted that large part of the land in Kilombero District that was initially used by pastoralists is now reserved as the Kilombero Floodplain Ramsar Site where no anthropogenic activities are allowed. The current climate stresses in the area like increases dry spells and floods have increased competition and sometimes became a cause for conflicts over resources particularly on water sources and pasture in Kilombero District. Such situation has led to decrease in livelihood resources for human well-being, increased outbreak of human and livestock pest and diseases, therefore making households in Kilombero to come up with different strategies to cope and or adapt with such a situations including use of NTFPs.

The climate change adaptation strategies may be explained by the use of different theories. Some of the selected theories relating to this study include; a theory of cognitive adaptation by Taylor (1983), theory of adaptation as a public good by Seo (2010a); and action theory of adaptation by Eisenack and Stecker (2011). The following sections explain relevance of these theories to the current study.

2.3.1 Theory of cognitive adaptation

A cognitive adaptation theory was first proposed by Taylor (1983) embracing adaptation as a process occurring after a threatening event such as a chronic disease. The theory argues that when individuals experience personal tragedies or setbacks, they respond with cognitively adaptive efforts that may enable them to return to or exceed their previous level of psychological functioning. In line with this, Wong and Weiner (1981) mentioned that during threatening or dramatic event, individuals make attribution to understand, predict and control their environment. Such an approach is relevant to how households may understand climate change and respond with diverse strategies. Use of NTFPs for both subsistence and trade is among the strategies, which households have developed in order to gain livelihood outcomes such as improved food and health security, income and wellbeing.

Successful adaptation to victimization or dramatic event is accomplished through engagement in a series of mildly positive self-relevant cognitive distortions (Taylor, 1983). That is, the adjustment process in response to a threatening event involves a search for means, an effort to gain mastery, and an attempt to enhance the self. Cognitive processes address means by finding a causal explanation for the experience and restructuring the meaning of one's life around the setback. Masterly involves efforts to gain control over the threatening event in particular and over one's life more generally by believing that the one has control and by exerting behavioural control over threat-related events such as floods and droughts. Self-enhancement occurs by comparing oneself with others who are less fortune, and by focusing on aspects of one's own situation that make one appear to be well off. Cognitive adaptation theory is as an alternative model of the disconfirmation process, because it offers a very different view of human organisms than do currently available models. It views people as adaptable, self-protective, and functional in the face of setback.

2.3.2 Adaptation as a public good

Adaptation as a public good builds on the current adverse effects of climate change that has no boundary as it impedes livelihood sustainability to all individuals. According to

Cowie (2007), climate change is a global concern to people and their livelihoods. It can be argued that potential impact of climate change will hinge substantially upon whether or not an individual or a community is able to take protective measures (Seo, 2010a). Arguably, some climate change impacts are global and occur to every individual like flooding, rise in sea level, and increased temperature. However, the sensitivity and magnitude of the impact may differ from community to another or from one individual to another because of difference in adaptive capacity (Adger *et al.,* 2007). Climate change impacts on agriculture could be large if households in developing countries do not adapt to a new climate condition, but it could be minimized by adopting more resilient farming system and heat tolerant species of crops and livestock (Seo and Mendelsohn, 2008; Seo, 2010b).

An increase in disease incidence may affect poor developing countries severely. At the same time, they can similarly reduce the potential vulnerability by improving their well-being through use of available resources for example by improving medical systems. Adaptation is feasible because climate is likely to change gradually over the next hundred years and it is in the interests of the victims to minimize the damage (Seo, 2010a).

This theory further argues that adaptation measures that are taken at the individual level can take place without the need for government interventions. Individual adaptations such as switching livestock species, crop varieties, agricultural systems, forest products, land uses do not necessarily call for governments to be involved since these adaptation measures will benefit the individuals who take them (Seo, 2010b). The present theory is contrary to other scholars who argued that individual adaptations could be aided by the governments efforts (Kelly and Adger, 2000; Ziervogel and Calder, 2003; Vogel *et al.,* 2007; Moser, 2010; Moser and Ekstrom, 2010).

Individual adaptation needs to be aided by policy or a change at other levels since local vulnerability is often driven by processes that are not only local, such as economic restructuring, marginalisation, conflict. Similarly, the current study has observed interventions by the government and private sector companies in increasing adaptive capacity to households. Some of the interventions by the government and private sector include provision of camping facilities during floods, relief food for households to cope with food shortage, mosquito nets as a protective measure against malaria. In addition, the government in Kilombero District has provided education on sustainable supply of NTFPs, which includes domestication of the potential indigenous tree species as well as market improvement of the products. In totality, the current theory does not provide long-term solution for households to adapt to climate change adverse effects, also taking into consideration equity and justice principles. Individuals and households can take actions on their own, but there as drivers of vulnerability are often higher level structures and policies, there are limitations to what they can do without changes in policies and structures (Ribot, 2009).

2.3.3 Action theory of adaptation

The theory analyzes adaptation from an action-oriented perspective. The theory reflects on access to resources that are called means towards adaptation. The resources can be "access to financial or other material resources, legal power, social networks, knowledge and availability of information for sustainable adaptation" (Eisenack and Stecker, 2011). The theory proposes a way to think about adaptation that emphasizes the interconnectedness of complex activities that address societal consequences of climate change along means-end chains, and considers multiple actors in different roles. It is crucial for analysis to spell out the purpose of adaptations, and to consider that operators and receptors of adaptation may be different from the exposure units (Eisenack *et al*., 2011).

For the core concepts of the action theory of adaptation, it is not sufficient to consider social processes alone, as might be appropriate for a purely sociological issue. When considering adaptation to climate change, the relation of actions beyond social processes and actions is always emphasized, as far as the inter-linkages to the natural environment are crucial. It is important to deal with an interdisciplinary problem of interlinked biophysical and socio-economic systems. The theory is in line with arguments by O'Brien *et al.* (2007) about conceptions of contextual vulnerability, since it is possible to focus on the means and conditions for operators independently from the actual occurrence of event. O'Brien *et al.* (2007) distinguish outcome vulnerability and contextual vulnerability, in such a way that, the outcome vulnerability takes it as the residual effect of climate change after adaptive responses have been taken. Contextual vulnerability puts the exposure unit into the centre. Adaptation to climate change can be targeted at changing contextual conditions or at reducing damage.

The current theory is related to that by Seo (2010a) which is about adaptation to climate change as a public good. They both argue about availability of resources to people for exercising climate change adaptation. However, the current theory by Eisenack and Stecker (2011) insists about access to the resources that enhance livelihoods of the people. This theory is relevant in the context of the current study, where access to resources by households is restricted. To reduce vulnerability of the households to recurrent climate change adverse effects it is important to promote sustainable management and utilization of the existing village forests and woodlands.

2.4 Climate Change and Livelihoods

2.4.1 Overview on climate change

Climate change is a global development phenomenon and among the key challenges that influence livelihoods of households in developing countries. Developing countries are especially vulnerable to the negative effects as they are often geographically located where climate change is likely to have often damaging impacts, with least capacity to adapt (Stern, 2007). According to Tumbo *et al.* (2011), the adverse effects of climate change are already taking their toll on the livelihoods of Tanzanian people and in key economic sectors of such as agriculture. The expected climate change effects in different areas and sectors in Tanzania are detailed in the National Adaptation Programme of Action (NAPA) document (URT, 2007). Humid areas of Tanzania are among the geographic areas in which livelihoods are vulnerable because of the extreme weather events like flooding and dry spell periods (Chamwali, 2000; Starkey *et al*., 2002; and Harrison, 2006).

Kilombero District being among the humid areas of Tanzania has also experienced increased temperature and precipitation over recent years (URT, 2012a). The district receives high annual temperature that ranges from 26 ^{0}C to 32 ^{0}C, and rainfall from 1 200 to 1 800 mm (Erlanger *et al.,* 2004; Hetzel *et al.,* 2007; 2008). Climate predictions in Tanzania (URT, 2005; 2007) show that the mean daily temperature will rise by 3 – 5^{o}C throughout the country and the mean annual temperature by 2 – 4^{o}C. Predictions further show that areas with a bimodal rainfall pattern including Kilombero District will experience increased rainfall of 5–45%. The predicted weather conditions for Kilombero District indicate increase in uncertainty, possibly few dry spell periods but also risk of flooding. Increased temperature in the study area also exacerbates dry spells.

According to the Fifth Assessment Report of the IPCC (Niang *et al.,* 2014) warmer and more humid conditions caused by climate change could impact food availability and utilization through increased risk of spoilage of fresh food and pest and pathogen damage to stored foods that reduces both food availability and quality. According to Pittock (2009), the trend of increase in temperature and precipitation is expected to increase in future globally that will perpetuate persistence of warm and humid conditions. According to NAPA (URT, 2007), it is predicted that the mean daily and mean annual temperature will rise by between 3^oC and 5^oC 2^oC and 4^oC respectively by 2050 throughout the country. The report also showed that there would also be an increase in precipitation in some areas while others will experience decreased seasonal shifts in precipitation. In Tanzania, humid areas experience annual precipitation of about 1600 mm and above, with temperature ranging from 22 to 32 ^oC (URT, 1997). However, precipitation in humid areas has not been constant over time, as it has been varying over seasons and years.

The global climate change problem is among other things a result of human economic activity, through emission of greenhouse gases, and will continue over the next few decades even if dramatic mitigation measures are introduced now. Scientists argue that, what is changing the climate is the 'enhanced greenhouse effects' (Pittock, 2009; Tietenberg and Lewis, 2012). It is predicted that the impacts of the future climate change will have several harmful effects on people's livelihoods (Common and Stagl, 2005). Similarly, Niang *et al.* (2014) revealed that climate change has the potential to impose additional pressures on livelihood of the people in Africa. This is also in line with Somorin (2010) observation that rural poor people tend to suffer more than others do when extreme events like frequent floods and droughts, tropical storms and landslides occur. This happens for three reasons; first, they live in areas and shelters that are more susceptible to these extreme events. Second, they do not have the resources to cope with these events. Third, the poor in developing countries cannot depend on social opportunities as safety nets to cushion the impacts of extreme events. In addition, most of them depend on rain-fed agriculture, which is influenced by climate.

2.4.2 Effect of climate change on livelihoods

Climate change exacerbates concerns about livelihood resources particularly agricultural production and food security worldwide. However, in most cases, food security is prominent among the human concerns and ecosystem services under threat from dangerous anthropogenic interference in the earth's climate (Pittock, 2009). Among the adverse effects of the prospective climate change on human systems is reduced crop yields in most tropical and sub-tropical regions due to flooding and dry spells. Others include decreased water availability for household consumption; increase in human exposure to vector-borne (e.g. malaria) and water-borne (e.g. cholera and dysentery) diseases; pests; increase in heat stress mortality; increased risk of flooding – more heavy precipitation events and sea-level rise (Common and Stagl, 2005; Pittock, 2009). Existence of multiple socio-environmental stressors, including economic and political changes such as conflict or economic marginalisation, exacerbates people's vulnerability to such climate change impacts, thus minimizing livelihood growth level within the communities (Klein *et al.,* 2007).

According to Wolf (2011), vulnerability highlights the level in which individuals, communities, and regions are differentially at risk from the effects of climate change. This calls for adaptation measures, which include traditional coping strategies, infrastructural, and economic response capacity to effect timely response actions (Somorin, 2010). In connection to this, Ruettinger (2012) mentioned that poor population groups might not have the financial and technical capacities to develop resilience or adaptation to climate change effects. For example, subsistence households normally depend on rain-fed agriculture as their sole source of income, which is however not sustainable as rainfall is now not predictable. It has also been mentioned that, specific livelihoods and poverty alone do not necessarily make people vulnerable to weather events and climate; but also the socially and economically disadvantaged and the marginalized groups are disproportionately affected by the impacts of climate change and extreme events (Olsson *et al.,* 2014). The increasing marginality of many low caste communities causes disaffection with traditional management and, in some cases, a limited adherence to new rule structures (Robbins, 2012). In some cases, limited livelihoods flexibility causes marginalization among social groups which includes the gender, age, class, race, (dis)ability, or being part of a particular local or ethnic group. Vulnerability is often high among local people, women, children, the elderly, and disabled who experience multiple deprivations that inhibit them from managing climate change adverse effects (Olsson *et al.,* 2014).

2.5 NTFPs and Livelihoods

Non-Timber Forest Products (NTFPs) have been observed in various contexts to provide livelihood options to households in the face of climate related events. NTFPs serve households during emergency shortfalls and keep them from being worse in times of need (Belcher, 2005; Shackleton *et al*., 2011). They are utilized by household and currently act as safety nets not only in provision of essential nutritional supplements but also serving as an immediate livelihood resource against experienced climate change effects (Paavola, 2008; Nkem *et al.,* 2010; Shackleton *et al*., 2011). The NTFPs are contemporary used for subsistence and trade. Use of NTFPs by households for adaptation to climate change can be assumed more reliable compared to products from monoculture plantations because they are produced from the natural forests, which are more resilient to climate change effects (Smith *et al*., 2014b). FAO (1999) defined NTFPs as all biological materials other than timber, which are extracted from forests, other wooded lands and trees outside forests for human use. The status of knowledge regarding the use of firewood, building poles, edible wild mushrooms, wild fruits, thatch grasses, medicinal plants, wild meat, wild vegetable, honey, ropes, gums and resins in livelihoods is described in more detail below.

2.5.1 Firewood

Firewood is among the major forest product which is also a main source of energy in sub-Saharan countries (Shackleton *et al*., 2011), where in South Africa, over 80% of the rural households are reported to use firewood to some extent. Tanzania is among the sub - Saharan countries in which 98% of the population in the rural areas depend on firewood as source of domestic energy (Monela *et al.,* 2005). Substantial increase in human population, climate stresses as well as decreasing forest areas have led to firewood shortages being reported in many countries. Firewood is used for food preparation, heating, beer brewing, tobacco curing, brick burning, fish and meat smoking as well as lighting in rural households. Most tree species particularly from Miombo woodlands are reported suitable and useful for firewood. Some of the tree species suitable for firewood in Tanzania include *Brachystegia spiciformis* Benth., *B. boehmii* Taub., *Afzelia quanzensis* Welw., *Combretum molle* (R.Br. ex G.Don), *C. collinum* Fresen., *C. zeyheri* Sond., *Terminalia sericea* Burch. ex DC., *Zanha africana* (A. Rich.) Engl., *Pericopsis angolensis* (Baker) Meeuwen, *Julbernadia globiflora* (Benth.) Troupin, *Berchemia discolour* (Klotzsch) Hemsl. and *Azanza garckeana* (F. Hoffm.) Exell et Hillc. (Njana, 2008).

Preference of tree species for firewood by individuals is mainly based on the following attributes; medium to high wood density, low moisture content, low smoke yield, long-lasting coals, absence of thorns, and absence of unusual fumes (Abbot and Lowore, 1999; Luoga *et al.,* 2002; Njana 2008). Size of the firewood is also an important character by the collector, however is always influenced by the end use purpose. Abbot and Lowore (1999) observed that collectors of firewood for household domestic energy in Malawi targeted branches and stems of about 3 – 8 cm butt diameter, with a mean of approximately 5 cm.

In most cases of the African societies, it is widely recognised that women are the main collectors of firewood for domestic use (Abbot and Lowore, 1999). However, women and girls do collect most of the firewood of smaller size classes but very little of the larger diameter, which are left for the men and boys. During collection of firewood, women usually use small tools (such as machetes), and when cutting lopped branches they could reach instead of felling the whole trees. Thus the diameter class harvested is limited by the tools used as well as transportation means. Most of the women and girls use head loads to transport firewood, usually the head loaded bundle. Similarly basing on the utility of the firewood, most of the firewood collected by women is being used under the traditional three stone fire stove. The kind of firewood collected by women or girls is also determined by its final utility (Abbot and Lowore, 1999).

2.5.2 Building poles and withies

The use of woodland materials for construction is a common practice in most rural areas of sub-Saharan Africa (Shackleton *et al*., 2011). Building poles and withies are among the NTFPs derived from small diameter tree trunks and branches. Poles for buildings have been used since ancient times all over the world. In South Africa rural inhabitants use poles and withies gathered from surrounding woodlands to construct traditional structures such as huts, granaries, fence, animal kraal and utensils (Makhado *et al.*, 2009; Shackleton *et al*., 2011). In rural structures, and farm buildings wood is often used in the form in which it has grown, that is round poles. In some areas where enough trees are grown in closed forests, open woodlands, or on the farm wooden poles can be obtained at very low cost. These poles have many uses in small building construction, such as columns for the load bearing structure and rafters. Sticks and thin poles are often used as wall material or as a framework in mud walls (Luoga *et al.,* 2000). Where straight poles are selected for construction, it is as easy to work with round timber as with sawn timber.

In South Africa, Makhado *et al.* (2009) observed that cost of the poles was usually determined by its size, rather than the mass. In Tanzania, preference and price for building poles and withies was determined by several attributes, which include type of species, size, strength, and resistance to splitting as well as durability to termites attack, air and soil moisture as well as other wood biodegraders (Luoga *et al.,* 2000). Similarly, Mbeyale (1999) working in communities surrounding the Amani Forest Nature Reserve noted local people being selective with species used as building poles, as among the important qualities were durability and straightness of the tree and therefore influencing the price. On the other hand, Maximillian (1998) in her survey of the uses of forest products in villages surrounding North Ruvu Forest Reserve reported about 90% of the houses being built from poles and withies. In line with this, Mbeyale (1999) working in communities surrounding the Amani Forest Nature Reserve observed about 98% of the houses being built using poles. The studies done in Tanzania indicate that, households particularly adjacent to forests still depend on building poles for house construction.

2.5.3 Thatch grasses

Thatch grasses are harvested annually from the surrounding woodland by rural people for roofing (Schaafsma *et al*., 2014). The majority of rural communities use dry grass for thatching buildings and making fences around compounds. Thatch grasses are widely used for roofing, because are considered to be cheap and a traditional building material (Monela *et al.,* 2005). In miombo areas, grass species that provide useful thatching material are abundant (Campbell *et al*., 2008). Thatch collection is expected to have a less detrimental effect on forests than fuel wood or pole collection, and is an important ecosystem service to communities (Schaafsma *et al*., 2014). Lema (2003) reported that about 48% of the households surveyed in Morogoro Rural District, Tanzania used an average of 17 head loads of thatch grass per household per year for roofing. Maximillian (1998) reported consumption of 40 head loads of thatch grass per household per year in Kibaha district, Tanzania. Hassan *et al*. (2002) found that the consumption of thatch grass in Swaziland was estimated at an average of 30 head loads per house unit per year.

There is currently a high demand for thatching grass, even for thatching modern structures such as restaurants and guesthouses or camps. Apart from thatch grasses being used in rural for roofing, they are nowadays much preferred in such structures for cooling particularly in areas that experience high temperatures especially in cities and municipalities. In Tanzania, this is common to most of the cities and municipals around the coast of the Indian Ocean like Tanga, Dar es Salaam, Morogoro, Pwani, Lindi and Mtwara. Therefore, there is high potential of the market for thatch grasses in future from subsistence to commercial product. Some of the common grasses harvested for thatching in Kilombero District include *Vetiveria nigritana* (Benth) Stap and *Hyparrhenia spp*. *Vetiveria nigritana* species are much preferred for roofing compared to the *Hyparrhenia* *spp.* because of its life span while in service that goes up to four years (Kato, 2007; Laswai, 2011).

2.5.4 Medicinal plants

Medicinal plants form the basis of traditional or indigenous systems of healthcare used by a large portion of the population in most developing countries. According to Garrity (2004), more than 80% of the rural communities in sub-Saharan Africa depend on medicinal plants for most of their health care needs and for income generation. Shackleton *et al*. (2011) revealed that medicinal plants offer - self-medication to most of the rural communities. Use of medicinal plant is one of the most important ways of making a livelihood for those who have no other means of getting health services to carter for various diseases in formal hospitals (Michael *et al*., 1996; Shackleton *et al*., 2011; Bruschi *et al.,* 2014).

A number of ethnobotanical studies carried out throughout Africa confirm that indigenous plants are the main constituent of traditional African medicines and they treat different diseases of human being (Cunningham *et al*., 1993; Abo *et al.,* 2008; Koffi *et al*., 2009; Warda *et al*., 2009; Nahashon, 2013; Bruschi *et al.,* 2014). Medicinal drugs derived from natural source make an important global contribution to health care. It is evident that, most of the households in Tanzania have developed complex and sophisticated knowledge system about the use of vast diversify of plants for medicinal purposes (Makonda, 1997; Nahashon, 2013). Medicinal plants are harvested from the surrounding woodland by traditional healers and herbalists for treating illness and selling in the nearby markets (Nahashon, 2013).

There are several plant species with medicinal value found in forests and woodlands. Some of the trees with medicinal values found in miombo woodlands of Tanzania include; *Afzelia quanzensis* Welw*., Annona senegalensis* Pers., *Cassia abbreviate* Oliv., *Combretum binderianum* (Kotschy) Okafa, *C. collinum* Fresen*., C. molle* (R.Br. ex G.Don)*., C. zeyheri* Sond*.*, *Dichrostachys cinerea* (L.) Wight & Arn., *Diplorhynchus condylocarpon* (Müll.Arg.)*, Diospyros mespiliformis* Hochst. ex A.DC.*,* and *Harissonia abyssinica* Oliv. Others are; *Kigelia africana* (Lam.) Benth.*, Pterocarpus angolensis* DC.*, P. tinctorius* Welw., *Rhus natalensis* Bernh. ex C.Krauss, *Sorindeia madagascariensis* DC*, Tamarindus indica* L.*, Vangueria apiculata* K.Schum.*, Vitex mombassae* Vatke and *Xeromphis obovata* (Hochst.) Keay (Paulo, 2007; Kilonzo, 2009; Augustino *et al.,* 2011; Nahashon, 2013). Tree species preferences for medicinal use depend on the knowledge of the user and the number of cures each species offers. Studies show that, some of the trees species have multiple uses in such a way that they serve more than one purpose thus their promotion must take into consideration such values (Augustino, 2006; Njana, 2008).

The dependency on traditional medicine is perpetuated by the fact that artificial medicinal care is limited in rural areas, and where it is available, the costs are relatively high (Makhado *et al.,* 2009). Similarly, Kayombo *et al.* (2013) reported about the role of traditional medicine in primary healthcare in Tanzania especially in rural areas where health facilities, medical personnel, drugs and other medical supplies are inadequate. For example, a remedy for HIV/AIDS is currently not available, and in most cases, there is an increasing dependency on traditional medicine to treat HIV/AIDS related illnesses.

2.5.5 Edible wild mushrooms

Edible wild mushrooms are important forest food products, which are delicious by many people. Mushrooms are known to be abundant in the Miombo woodlands in Southern

Africa and in Tanzania (Harkonen *et al.,* 2003) because almost all of the trees are ectomycorrhizal. They typically grow on dead organic matter, mostly in woodlands. According to Munyanziza (1996), the yield of mushrooms depends on the nature of the substrate, air humidity and temperature, moisture of substrate and other competing organisms. Higher growth rate of mushrooms is generally at 30 ^{o}C with a maximum soil pH of between 4.0 and 6.0 (Raymond *et al.,* 2013). Mushrooms are frequently collected by the local population, mainly for own consumption. Fresh, but also dried mushrooms are sold at market places and along roadsides. Many of the mushrooms are edible and have high nutritional and energy values (Harkonen *et al.,* 2003). They serve as sauces and relishes to accompany the stable dishes and are often consumed as meat substitutes. Mushrooms are also good sources of protein and minerals.

A study by Morais *et al*. (2000) indicated that mushrooms have a protein content of between 27% and 48%, 60% carbohydrates and between 2% and 8% of lipids. Mushrooms are therefore, appreciated for their nutritional value particularly in rural areas. Apart from having nutritional value, mushrooms have also medicinal value. In Tanzania, mushrooms have been reported to treat cough and asthma (URT, 2008). In India, China and Japan mushrooms have been traditionally used since time immemorial as a remedy for patients suffering from hypertension, liver diseases, stomach ulcers, diabetes and coronary heart disease (Sharma *et al.,* 2009).

In Tanzania there are over 60 edible wild mushroom species already identified (Harkonen *et al.*, 2003, Tibuhwa *et al.,* 2011). Some of them include *Auricularia auricle* (Hook.), *Coprinus cinereus* (Schaeff) S. Gray, *Volvariella volvaceae* (Bull.ex.Fr) Singer, and *Pleurotus flabellatus* (Berk and Br.) Sacc, *Amanita loosii* Beeli, *Cantharellus isabellinus* Heinem*, C. floridula, C. platyphyllos, Laetarius volemodes* (URT, 2008; Mshandete and

Cuff, 2008). In rural areas of Tanzania, most of the edible wild mushrooms are obtained from the forests particularly in the Miombo woodlands (Munyanziza, 1996). At the same time, these forests and woodlands are depleted due to different anthropogenic activities, which could lead to extinction of many edible wild mushrooms species (Harkonen *et al.,* 2003). To ensure sustainability and availability of the wild edible mushrooms in Tanzania, domestication and cultivation of the preferred mushrooms species is being undertaken (Mshandete and Cuff, 2008; Mwita *et al.,* 2011). Mushroom cultivation provides an opportunity for improved households' livelihoods and reduces dependency on natural resources.

2.5.6 Wild fruits

Most of the wild fruits have been recognised to have higher vitamin contents than exotic fruits. For example *Adanisonia digitata, Ziziphus jujube* and *Ximenia caffra* have higher vitamin C content than that in *Mangifera indica* (mango), and *Citrus sinensis* (orange) (Ruffo *et al*., 2002). For example, vitamin C content of an orange is 57 mg/100 g while that of *Adanisonia digitata* is 360 mg/100 g and *Ziziphus jujube var. spinosa* is 1000 mg/100 g. Wild fruits like *Syzgium quineense* are very rich in iron (Saka, 1994). A study by Maghembe *et al*. (1998) on nutritional values of some indigenous fruits found that, *Strychnos cocculoides*, *Parinari curatellifolia* and *Azanza garckeana* contained more than 30% fat and about 45% crude fibre and total carbohydrates. The indigenous fruits contain organic acids such as malic, citric and tartaric which are good preservative for soft drinks and sources of flavour and aroma (Kochhar, 1981). In Mwanga and Lushoto districts, Tanzania communities use *Passiflora edulis* and *Telfairia pedata*, which are indigenous fruits and nuts respectively to generate income (Kapinga *et al.*, 2009).

In addition to nutritional values observed from different studies, fruits and their processed products provide food security during periods of food shortage and in years of famine that might be due to either climate stresses or other causes. A study by Simwanza and Lungu (1998) observed that wild fruits play an important role of securing food during periods of food shortage in Zambia. The study (*ibid*) showed that, there were people who survived on *Parinari curitellifolia* fruits and were quite healthy even after going through a serious famine for some days. Similarly, Ramadhani *et al*. (1998) found that communities used the dry pulp of *Parinari curatellifolia* and *Uapaka kirkiana* mixed with small portions of sorghum flower to prepare stiff porridge for their families during periods of food shortage in Tanzania.

2.5.7 Wild vegetables

Wild vegetables have been in use by human beings for a long time as they are good source of nutrition for different age groups (Msuya *et al.,* 2010). Wild vegetables are important source of vitamins (example vitamin A, vitamin C and folic acid), mineral, proteins, carbohydrate and fats. In most cases, these wild vegetables have comparable and sometimes superior nutritional quality to domesticated varieties. For example, Falconer and Arnold (1991) observed some of the wild vegetables that are good sources of vitamins and minerals like *Cassia obtusifolia* (vitamin C – 120 mg/100g), *Balanites aegyptiaca* (calcium – 37 010 mg/100 g), *Adanisonia digitata* (niacin – 8.1 mg/100g, energy – 1180 kj/100g, calcium – 2600 mg/100g, vitamin A – 1618ug/100g, protein – 13.4% of calories) and *Leptadenia hastata* (iron – 95 mg/100g). Similarly, wild vegetables supply roughage, which facilitates digestion and prevents constipation (Kochhar, 1981).

2.5.8 Ropes

Ropes are fibrous materials extracted from barks of some tree species used for tying together materials. The most common plant species that produce ropes include: *Brachystegia boehmii, B. spiciformis, Hyphaene compressa, Parkia filcoidea, Phillipia benguelensis*, *Piliostigma thonningii, Sterculia appendiculata, S. quinguloba,* and *Terminalia sambesiaca* (Paulo, 2007). Ropes are used for tying building materials mostly poles, withies and grasses instead of nails, which are relatively expensive to most of the people in rural areas. Other uses include tying head loads of firewood, weaving materials, poles and withies. Strong woven ropes used to make traditional beds. In Zambia, Syampungani (2008) observed *Brachystegia boehmii* being among tree species commonly used for ropes production for various domestic used because of its ropes being strong and easy to peel. The *Brachystegia boehmii*, ropes are also used for making charcoal bag heads as well as tying up poles and withies during house construction in rural areas.

2.5.9 Wild meat

Wild meat is still the only reliable source of animal protein in several parts of Africa (Aiyeloja and Ajewole, 2006; Shackeleton *et al.,* 2011). Wild meat is a good source of protein obtained through hunting of small mammals, ranging from small rodents to antelopes (Shackeleton *et al.,* 2011). Larger species may also be trapped or hunted, but populations are very low in regions with high human population densities, and so the smaller species comprise the bulk of the wild meat intake (Nielsen, 2011; Bakengesa *et al*., 2012). In Tanzania, wild meat is becoming increasingly important, as a source of protein, cash income and preparation of traditional medicines (Nielsen, 2004; 2011). In Nigeria, Aiyeloja and Ajewole (2006) observed both visceral and bones from many wild animals being used in preparation of medicine for different ailments, whereas skin, horns, feathers and shells are used for decorations. Nielsen (2011) found that, inadequate livestock available to among households in the Kilombero Nature Reserve prompted them to be involved in wild animal hunting to supplement protein requirement.

Currently hunting equipment for wild animals in forests and woodland reserves is almost similar to all ethnic groups in Tanzania. Rovero *et al.* (2012) noted that currently hunters are using different snares, traps and dogs for hunting wild animals unlikely to the past between 1965 and 1975, and the mid-1990s where guns made locally were much used. The reason behind this is due to not only disappearance of larger species but also few medium-sized species exist.

2.5.10 Honey and bees wax

Honey is the natural sweet substance produced by honeybees from the nectar of blossoms or from the secretion of living parts of plants or excretions of plant sucking insects on the living parts of plants (Krell, 1996). Honeybees collect secretion from living plants, transform and combine with specific substances of their own, store and leave in the honeycomb to ripen and mature (Krell, 1996). Beeswax is obtained from the honeycombs of bees after the honey has been removed by draining or centrifuging (Krell, 1996). Honey, is the world's oldest sweetener, until sugar cane was cultivated on a large scale in the New World. In ancient literature, honey and honeybees are mentioned with much feeling and gratitude for their bounty. The Bible speaks of a land "flowing with milk and honey" (Krell, 1996; Medhi *et al.*, 2008). Honey is often eaten as energy food. Its simple sugars are absorbed directly into bloodstream without digestion. Apart from the honey being food, honey is believed to have medicinal properties, it helps against infections, promote tissue regeneration, and reduce scarring (Hutton, 1996; FAO, 2009). Traditionally, when honey is used pure or mixed with other ingredients, it cures coughs, stomach aches, ulcers, malaria and burns or scalds (Krell, 1996; FAO, 2009). Honey is also used in wound dressing leads to rapid healing by stimulation of healing process, clearance of infection, cleansing action of wounds, stimulation of tissue regulation, reduction of inflammation and non adhesive tissue dressing (Medhi *et al*., 2008).

Tanzania has high level of production of bee products especially honey and beeswax. The high production of bee products in Tanzania is mainly due to presence of a high population of bee colonies that are estimated at 9.2 million, and also due to presence of high number of vegetation that are preferred by bees in many areas of the country (Kihwele *et al*., 1999). Beeswax which among other things, is used in the manufacture of cosmetics, candles, foundation sheets for hives, medicines and polishes, had a good and very stable market. The presence of Miombo trees species such as *Brachystegia, Julbernadia, Isoberlina, Combretum* and *Terminalia* also contributes significantly to the high production potential of bee products in the country (Kihwele *et al*., 1999).

Honey is among the NTFPs that ensures non-consumptive use of forest resources with a wide range of customers from both urban and rural settings. Munishi *et al.* (2009) observed that, local communities earned a minimum annual income of TZS 628 313 from sales of honey in Iringa and Mbozi districts. Most bee products including honey are for home consumption, but any marketable surplus can provide a safeguard and security against crop failures or for use between crop harvests (Nair, 1993). Income generated from beekeeping can be used to pay for education, health, transport and housing. Honey is also used to make local brew popularly known as '*wanzuki',* which is very common in some parts of Tanzania especially Tabora and Iringa regions, Tanzania. Similarly, Clauss and Clauss (1991) reported that honey is widely used to make honey beer in Kenya. Therefore, honey is an important NTFP, which improves the livelihoods of the households especially under the current change in climate through provision of food as well as medicinal value for different remedies.

2.5.11 Gums and resins

Gums and resins are among the most widely used and traded NTFPs (FAO, 1995). Gums are products that are obtained from plants. They are solid materials consisting of mixtures of polysaccharides (carbohydrates) which are either water-soluble or absorb water and swell up to form a gel or jelly when placed in water. Gums are used as thickening, stabilizing, emulsifying and suspending agent in food and drink industries; as tablet-binding agent and cream and lotions suspending and emulsifying agents in pharmaceuticals, as film forming and sizing agent in printing and textile industries (FAO, 1995; Avachat *et al.,* 2011). Resin is a solid or semi-solid material, usually a complex mixture of organic compounds called terpenes, which is insoluble in water but soluble in certain organic solvents. Resins have an equally diverse range of applications, in medicines, in paints, adhesives and dyes manufacturing, varnishes and lacquers and in flavours and fragrances (Avachat *et al.,* 2011).

However, the use of some of these products has declined because of competition from synthetic products (FAO, 1995). Some of the tree species that produce gums and resins in Africa include: *Acacia senegal* (L.) willd var. *senegal* and var. *kerensis*, *A. seyal* Del. var. *seyal* and var. *fistula*, *A. polyacantha* willd. var. *camplacantha, Acacia drepanolobium, Boswellia papyrifera* (Del.) Hochst, *B. neglecta* S. Moore, *Commiphora myrrha* (Nees) Engl. Syn. C. molmol, *C. africana* (A. Rich.) Engl., *C. habessinica* (Berg) Engl. (Makonda, 2003; Worku *et al.,* 2006; Tadesse *et al.,* 2007). In Tanzania, the dominant gum and resin producing species include; *Acacia senegal* (L.) willd var. *senegal* and var. *kerensis*, *A. seyal* Del. var. *seyal* and var. *fistula*, *A. drepanolobium, Boswellia neglecta* S.

Moore, *B. papyrifera* (Del.) Hochst, *Commiphora africana* (A. Rich.) Engl. and *C. spatulata* (Makonda, 2003; Mbwambo *et al*., 2006; Mturi *et al*., 2006; Balama *et al.,* 2009).

In some parts of Tanzania, such as Karatu (around Lake Eyasi), Mbulu and Iramba districts a tree species known as *Commiphora spatulata* have been used for decades to treat human and livestock diseases (Mturi *et al.,* 2006). The resin is believed to treat stomach diseases such as ulcers, skin diseases and wounds. The resin also is used as a repellent to mosquito and other biting insects. It is believed to cure trypanosomiasis for cattle and removes ticks and tsetse flies when applied on the animal body (Mturi *et al.,* 2006). Gums and resins are also used locally by the rural inhabitants as food (for pastoralists and hunters), medicine to treat colds, coughs, diarrhoea and rheumatism (Makonda, 1997; Makonda, 2003). Most of these products have a significant positive impact on rural household livelihoods particularly to women in terms of generating cash income and supplementing every day's diet (Makonda, 2003; Balama *et al.,* 2009).

2.6 Climate Change Adaptation as a Social and Political Process

This study sees climate change adaptation as a social and political process. This perspective is based on recent literature and insights regarding societal transformation, the political dimensions of adaptation, and the central role of social relation like gender dimensions in the adaptation process.

2.6.1 Climate change adaptation as a societal transformation

Climate change adaptation relates to social transformation in terms of contributing to creating a fundamentally new systems and social structures (transformative adaptation). Transformative adaptation can take place at many levels, including the local.

For example, households in Kilombero District may, as part of their adaptation strategies, undergo changes in social behaviour and structures and shift livelihoods, which would also be a form of adaptation. Adaptation involves changes in social-ecological systems in response to actual and expected impacts of climate change in the context of interacting non-climatic changes. Adaptation occurs through social learning, experimenting, innovating and networking to communicate and implement potential solutions (Kofinas and Chapin, 2009; Denton *et al.,* 2014). Adaptation strategies and actions can range from short-term to longer-term coping, while deeper transformation, aims to meet more than climate change goals alone, and may or may not succeed in moderating harm or exploiting beneficial opportunities. Similarly, Eriksen *et al*. (2008) explained that societal transformations influence vulnerability and the capacity to respond to climate-related shocks and long-term changes.

Moser and Ekstrom (2010) suggested that choosing a particular scope and scale of adaptation has significant implications for the number and types of barriers activated and encountered. System transformations will in future require different and likely more challenging barriers to be overcome than planning or implementing immediate measures to cope with a climate driven effect. In achieving this goal, social transformation is very important in such a way that it can takes place in terms of how people engage in activities, especially forest uses, diversification in agriculture, participation in casual employment, petty trade, remittances and pension payments, (Eriksen and Watson, 2009). However, lack of such opportunities might have negative influence on climate change adaptation in a particular community, as Robbins (2012), argued that lack of access to opportunity and unfair distribution of labour burden are commonly rejected and so become the source of political struggles.

2.6.2 Climate change adaptation as a political process

Climate change adaptation is highly influenced by political set up and processes of decision making in the society (Eriksen and Lind, 2008). It is clear that adaptation to climate change is long and time taking process, which involves different stakeholders including existing institutions and social organisations (Naess *et al.,* 2005; Eriksen and Selboe, 2012). According to Agrawal and Perrin (2009), institutions being public, civil or private are humanly created formal and informal mechanisms that shape social and individual expectations, interactions and behaviour. Institutions influence the livelihoods and adaptation of rural households in three ways; structures the spread of the climate risk impacts; constitutes and organizes incentive structures for household and community level adaptation responses; and mediates external interventions into local context (Agrawal and Perrin, 2009).

Livelihood resources with the communities are governed by the available and existing political structures (O'Loughlin *et al.,* 2012). Political structure indicates whether communities have access and right of ownership to a resource like land, forest, financial services, health services, market places. It is evident that, in some places, there are enough and available resources, which are vital for climate, change adaptation, but the communities have no access to them. For example, most of the communities in humid areas of Tanzania are adjacent to the Eastern Arc Mountains forests, which provide livelihoods to them. However recently the whole Eastern Arc Mountains forests have been upgraded to nature reserves, this includes the Iyondo Forest Reserve in Kilombero District and now the area has been proposed to be among the World Heritage Sites (URT, 2010c). Being nature reserves, there are restrictions on access to the resources particularly timber and NTFPs by the households in Kilombero District. From the nature reserve, people benefit other ecosystem services like water, clean air, and erosion control.

However, Robbins (2012) argued that the constructed relationship between nature and society is a type of materialist view of history, showing how different social organizations have been rooted in production, transformation and how people use the resource such as forests.

On the other hand, politics have a big role in climate change adaptation, especially in accepting and making adaptation strategies included in government plans and policies. Political adaptation has to be taken into account during people's adjustment to multiple shocks and stresses such as floods, droughts, pests, diseases and conflicts (Eriksen and Lind, 2008). The government policies are directions given to the communities on how resources can be accessed and used sustainably. However, in few cases policies and decisions might prioritise some interest and groups over others. Policies are essential in strengthening local adaptive capacity of the communities like improvement of education and making schools easily accessible. People with formal education have better access to labour and general understanding about climate change effects than uneducated ones. Capacity building (technical and financial) is important to communities not only to increase resilience but also adaptive capacity to the climate change extreme effects (Agrawal and Perrin, 2009). Adaptive capacity could entail the following for better and sustainable adaptation; livelihood resources, technology availability and access, availability and transfer of information and skills, infrastructure development, institutions and equity (Ensor and Berger, 2009; Tietenberg and Lewis, 2012). In order to have sustainable adaptation to climate change, it is important to support local strategies when implementing policies for development (Eriksen and Brown, 2011), for example existing indigenous or local knowledge over use of resources (Eriksen *et al.,* 2011).

2.6.3 Gender dimension in climate change adaptation

Gender is an important component in climate change adaptation. As climate change adaptation is a social process, gender relations is important in influencing this process and its outcome. It is clear that climate change effects across groups of gender are different. Climate change will affect women, men, children and old people differently. Studies show that some gender groups in a particular community like children, women and elderly people are much affected by climate change; this is because they are limited to some important social services that can increase resilience and adaptive capacity (Demetriades and Esplen, 2008; Ensor and Berger; 2009; Smith *et al.*, 2014a). This applies to Kilombero District as some of the social groups particularly women, children, elders and widows may become more vulnerable as they have few livelihood resources to enhance their adaptive capacity. It has been stipulated that, in many societies, women and girls face social and material barriers to accessing healthcare service (Demetriades and Esplen, 2008) due to limited economic assets with which to pay for healthcare as well as cultural and/or religious restrictions on their mobility, which may inhibit them from travelling to clinics. Agrawal and Perrin (2009) further observed that, poorer and disadvantaged groups in the community would suffer greatly from climate change effects, considering their economic activities are sensitive to climate changes.

Addressing inequitable gender dimensions, such as those excluding women from resources, decision making and particular livelihood activities, is important in enhancing adaptive capacity. It is possible that, if gender is not considered during adaptation processes it will become a barrier to adaptation. Moser and Ekstron (2010) revealed that, many barriers will make adaptation less efficient or less effective or may require costly changes that lead to missed opportunities or higher costs. Therefore for the adaptation strategies to be well taken by the communities, could consider gender as an important aspect.

2.7 Effects of Climate Change on Dynamics of Vegetation

Forest resources are not only important in people's adaptation strategies but also are part of the dynamic and such that themselves affected by climatic changes. Increase in greenhouse gases concentration has resulted in an increase in global temperature (Odum and Barrett, 2005). However, there is still considerable uncertainty regarding the effects of global warming on rainfall. Cowie (2007) noted that a warmer planet would have increased ocean evaporation and hence increased precipitation. Rainfall distribution is one of the main factors for the changes in vegetation dynamics in a particular ecological area. However, the effect of the change of rainfall distribution to vegetation varies depending on the forest types and location. According to Chidumayo (2011), altered temperature due to climate change might affect plant reproductive processes including flowering, pollination, seed production and seed germination.

Other studies have indicated that grasslands are more vulnerable to changes in rainfall than forests or deserts (Kaiser, 2001; Cowie, 2007). In the same vein, shrubs and trees will invade grasslands with an increase in rainfall, whereas desert shrubs will invade grasslands with a decrease in rainfall. Thus, it is clear that NTFPs like grasses, vegetables and medicinal from herb species may decrease if the dry spell period is prolonged (Cowie, 2007). However, Common and Stagl (2005) concluded that the effect of climate change on biodiversity is either positive or negative as some of the species may increase in abundance, while some vulnerable species will increase their risks of extinction, thus loss of biodiversity.

On the other hand, warming caused by greenhouse gases may cause increased evaporative power of the air, leading to increased transpiration by plants (Newman, 2000). It is also expected that, climate change will alter the geographical range within which particular crops can grow well (Cowie, 2007). According to Newman (2000), if climate gets warmer wild species including plants may respond as follows: continue in the same area, either because the new climate is within its existing tolerance range or because it adapts (that is, change genetically); migrate to a new habitat range, so remaining in a favourable climate; if it cannot do either of these it will become extinct. Toulmin (2009) has indicated that natural systems are normally resilient to a certain degree of climate variation and change, whereby plant species have relied on their genetic diversity to help them evolve over many generations.

Trees can adapt to long-term changes in environmental conditions by, for example, altering their pattern of growth and timing of flowering, fruiting and germination, to fit with the new constraints (Cowie, 2007; Ravindranath, 2007; Toulmin, 2009; Settele *et al*., 2014). According to IPCC Fifth Assessment Report by Smith *et al*. (2014b), forests especially the biodiversity rich tropical forests are more resilient to climate change impacts than monoculture plantations or any artificial forest. In this context, a forest consisting of multiple species are more resilient or less vulnerable due to different climate tolerance of different species, different migration abilities and effectiveness of invading species (Ravindranath, 2007). However, it is also important to recognize that although climate plays a significant role in determining species distribution, other variables such as human population density, land use and soils can have similar, if not more, important roles (Chidumayo, 2011). Issues of population growth and land use change therefore could be considered in developing adaptive strategies to climate change.

2.8 Valuation of Non-Timber Forest Products

The study uses valuation of non-timber forest products as an approach to understand the role of NTFPs in household adaptation in Kilombero District. The valuation includes both direct and indirect economic values.

2.8.1 Overview of economic value

The valuation of NTFPs, which are part of the ecosystem services, is a complex process that is reliant on the availability of relevant and accurate biophysical data on ecosystem processes and functions but also the appropriate applications of economic valuation (Morse-Jones *et al.,* 2011). In the past some environmental goods and services have been assigned zero or low values. This was due to difficulties involved in assigning economic values to such commodities or to the attitude that they are 'free goods'. Many economists have now studied the nature of these values; however, a useful starting point is the concept of aggregate or total economic value (Bateman *et al.,* 2003; Hanley and Barbier, 2009; Lusambo, 2009).

The economic value refers to the various benefits, which may be obtained from a natural resource (Bateman *et al.,* 2003; Tietenberg and Lewis, 2012). These benefits include the direct use value of a resource as an input to production or as a consumption good, its indirect use value through protecting or sustaining economic activity, and its non-use value to people who derive satisfaction the mere existence of a resource, even though they may never see it or consume any product obtained from it (Pearce and Moran, 1994; Hanley and Barbier, 2009; Tietenberg and Lewis, 2012). Similarly, Ozturk *et al.* (2009) described the total economic value as the sum of benefits including positive outputs classified as use values (direct and indirect), option value and non-use values (bequest and existence) and social costs including negative outputs such as damages by forest fires, erosion and floods. The total economic value, as illustrated in Table 1, provides a convenient framework for organizing the different classes of value that might be associated with NTFPs resources.

Use values arise from an actual use made of a given resource. This might be the use of a forest for timber, NTFPs or a wetland for recreation and fishing. Use values, the most commonly known of the two, refer to the capacity of a good or service to satisfy human needs or preferences. Use values can be direct, indirect or option. Whereas, non-use or intrinsic values, as the name suggests, are inherent in the good. That is, the satisfaction we derive from the good is not related to its consumption, *per se*. Non-use or passive use values consist of existence value and bequest value (Bateman *et al.,* 2003; Hanley and Barbier, 2009; Tietenberg and Lewis, 2012).

Table 1: **Economic taxonomy for environmental resource valuation**

Total Economic Value				
Use Values			Non-use (passive) Values	
Direct Use	Indirect Use	Option Value	Bequest Value	Existence Value
Value is generated from direct consumption of commodities	Value is generated from indirect consumption of commodities	Premium placed on maintaining forest for the future possible as per direct and indirect values	Use and non-use value of forest for future generation	Value people derive from the knowledge that something exists, for example forests, even if they never plan to use it
• Food • Biomass • Recreation • Health • Increased living comfort • Fibre	• Catchment protection • Erosion control • Nutrient cycles • Carbon sequestration • Microclimate regulation	• Biodiversity • Conserved habitats	• Preserving unique habitats, species • Prevention of irreversible change	• Habitats • Species • Genetic • Ecosystem

Source: Adapted from Pearce and Moran (1994); Bateman *et al.* (2003).

Direct use values

Direct use values can be consumptive or non-consumptive in nature (Pearce and Moran, 1994; Tietenberg and Lewis, 2012). Examples of direct use values in forestry include timber and non-timber forest products, but also non-commodity benefits such as forest recreation. Direct use is most obvious value category, as the economic benefits can be calculated by making use of market information. The outputs of the resource can be directly consumed. Examples of non-consumptive uses include camping, hiking and bird watching.

Indirect use values

Indirect use values refer to the benefits deriving from ecosystem functions such as a forest's function in protecting the watershed (Pearce and Moran, 1994). Indirect use of natural recourses relates to functional benefits, the outputs provide a social benefit from ecosystem functioning. It includes the role of forests in protecting watersheds and fisheries, and the storage of carbon in trees (to offset the atmospheric accumulation of "greenhouse" gases implicated in global warming).

Option values

Option value is like an insurance value, which reflects the value people place on a future ability to use the environment (Pearce and Moran, 1994). It reflects the willingness to pay to preserve the option to use the environment in the future even if one is not currently using it (Tietenberg and Lewis, 2012; Sumukwo *et al*., 2013) for example future visits to national parks, clean surface and ground water, avoiding of erosion to enable future use of pastures. It is that value attached to maintaining the possibility of obtaining benefits from ecosystem goods and services at a later date, including from ecosystem services that appear to have a low value now, but could have a much higher value in future because of new information. Option value reflects the desire to preserve the potential for possible future use. On the same way, the extent that option value is the expected value of future use of the resource; it may also be classified as a use value.

Another type of option value, which is not shown in Table 1, is “Quasi-option” value. Quasi-option” value is useful during decision making, for example a choice between conservation and development, however, the development option will result in an irreversible change. In this case, quasi-option value is the value of information that results after a decision has been made to develop or conserve now. For example, if a cure for a fatal disease were to be found after the conservation decision has been made, then quasi-option value would clearly be positive. It must be noted that quasi-option value cannot be summed with option value because it involves a different concept of economic value. Quasi-option value stems from the value of information gained by delaying an irreversible decision to develop a natural environment; it is not a value that individuals attach to changes in the natural resource (Tietenberg and Lewis, 2012).

Existence values

This non-use value reflects the “moral” or philosophical reasons for environmental protection, unrelated to any current or future use (Bateman *et al.,* 2003). Existence value is measured by the willingness to pay to ensure that the resource continues to exist in the absence of any interest in future use (Tietenberg and Lewis, 2012). According to Bateman *et al.* (2003), existence value arises from the benefit an individual derives from knowing that a resource exists or will continue to exist, regardless of the fact that he or she has never seen or used the resource, or intends to see or use it in the future. For example, people may value forests purely for its existence without the intension of using it directly in the future. Another good example of the significance of non-use value is the international outcry over the whaling issue. There are many people who have never seen a whale or plan to see one, but are willing to pay significant sums of money to ensure that whales are not hunted to extinction.

Bequest values

Bequest value, as the name suggests, is derived from the benefits that individuals obtain from knowing that a resource will be available for future generations (Hanley and Barbier, 2009). They are values that reflect the publics' willingness to pay to ensure future generations to enjoy the same environmental benefit in the years to come (Tietenberg and Lewis, 2012). For example, people may value forest as a bequest to their children. This also relates to the willingness to pay for preserving existing habitats, species and ecosystems. It also includes the willingness to pay to prevent for irreversible changes (for example, extinction of species).

2.8.2 An overview of the methods of valuing environmental products

Valuation methods are divided into two main categories: revealed preference (or indirect) approaches and stated preference (or direct) approaches (Hanley and Barbier, 2009; Tietenberg and Lewis, 2012). The revealed preference (that is, indirect) approach infers value indirectly by observing individuals' behaviour in actual or simulated markets. For example, the value of a wilderness area may be inferred by expenditures that recreationists incur to travel to the area. The value of, say, noise pollution may be inferred by analyzing the value of residential property near an airport. On the other hand, stated preference methods attempt to elicit environmental values directly from respondents by asking them about their preferences for a given environmental good or service.

Revealed preference approaches

Revealed preference approaches are those that are based on actual observable choices that allow resource value to be directly inferred from those choices (Tietenberg and Lewis, 2012). Revealed preference methods are observable because they involve actual behaviour and indirect rather than estimate it directly. Revealed preference methods include the market/costs methods, hedonic pricing method, travel cost method, and benefit transfer methods.

Market price methods

The market value approach is used to value environmental goods and services that have established markets (Tietenberg and Lewis, 2012). These are commodities, which have: direct uses: for example, timber, firewood, thatch grasses, commercial fisheries, tourism; some indirect uses: for example, the value of water from protected watersheds; and some option values: for example, gene research, forest conservation. The market value method attempts to find a link between a proposed environmental change and the market value of the corresponding goods and services. A common approach is to use changes in productivity of the good or service. For example, the direct impacts of an environmental change on human health can be estimated as a change in income. The assumption here is that sickness reduces one's ability to earn income. The limitations of the market value approach are as follows: (i) The types of values that it can capture are limited; (ii) It can be difficult to define the physical flows over time; and (iii) In some cases, the links between the environmental change and the market good or service may not be obvious.

Hedonic pricing method

The hedonic pricing method derives values for an environmental good or service by using information from the market price of close substitutes (Tietenberg and Lewis, 2012). Suppose the government wishes to value the disutility generated by aircraft noise in a given location. It could do this by analyzing variations in house prices with distance from the flight path of aircraft. Take the example of two houses with the same facilities (that is, number of bedrooms, bathrooms, and swimming pool), with one directly under the flight path and the other quite a distance away. It is expected that the house under the flight path will be cheaper and the price difference may be attributable to the value of the noise pollution. In practice, the analyst specifies a mathematical function where the price of a house is determined by various attributes.

The travel cost method

The travel cost method assumes that the costs that an individual incurs in visiting a recreational site are a measure of his or her valuation of that site (Tietenberg and Lewis, 2012). The approach involves asking visitors questions about where they have travelled from and the costs they have incurred. This information is then related to the number of visits per annum, to generate a demand curve for the recreational site under question. Since we expect people living near the site to make more visits per annum compared to those living far away, the demand curve will be downward sloping. The information requested in a travel cost survey includes the following: travel costs (petrol, food, and other travel-related expenses), income, alternative sites and personal motivations. Entrance fees to recreation sites are often non-existent or nominal. The demand curve drawn from the relationship between travel costs (a proxy for the price of recreation) and number of visits can be used to estimate the total recreation value of the given site.

Stated preference approaches

Stated preference methods they rely on the researcher directly asking people about their willingness to pay or willingness to accept compensation for changes in environmental quality (Hanley and Barbier, 2009). Stated preference methods can be either direct or indirect. The direct form of stated preference method is referred to as the contingent valuation method (CVM). Indirect stated preference methods include a variety of approaches including contingent valuation, choice modelling, substitute good value and barter values (Hanley and Barbier, 2009).

Contingent valuation method

Contingent valuation method is a common and consolidated stated preference method in environmental economics for valuing public goods (Hanley and Barbier, 2009; Wunder *et al.,* 2011). In most cases contingent valuation method is adopted during absence of any monetary or barter transactions whatever, whereby researchers pose direct questions to consumers about their willingness to pay for environmental benefits, or their willingness to accept compensations for losing them (Wunder *et al.,* 2011; Sumukwo *et al.*, 2013). This method has some critiques which include measuring preferences of the individual being questioned, which, unlike in a marketplace, includes not only a market price, but also the individual's consumer surplus.

Choice modelling

The choice modelling method adopts a particular view on how the demand for the environment is best pictured, known as the characteristic theory of value (Hanley and Barbier, 2009). This states that the value of a resource such as a forest is best explained in terms of the characteristics or attributes of that forest. The technique enables respondents to choose their most preferred resource use option from a number of alternatives. Usually, a number of attributes defines each alternative. For example, in a choice modelling study of preserving a wilderness area the attributes could be the following: numbers of rare species present; ease of access to the area, size of area and cost to households. These attributes are varied across the various alternatives. The respondents are then required to choose their most preferred alternative.

Substitute good values method

In this approach, marketable close substitute goods helps in providing useful value approximations (Wunder *et al.,* 2011). It requires establishing relative price between the priced and un-priced goods/products, which can be done based on product characteristics (Gunatilake *et al.,* 1993; Wunder *et al.,* 2011). For example, locally non-traded firewood is often being valued by comparing its energy content with commercial local close substitute such as gas and kerosene. This method therefore is used to calculate the values of the NTFPs that have no market price, but have close substitute with value in the village. The difficulty with this method lies in identifying products that can be considered close substitutes. Many factors have to be taken into account when choosing the products, including relative scarcity (that is, the difficulty involved in finding the product), taste preferences, size and social (non-market) attributes, such as the status of different products and tenure ship rights.

Barter values

This is another approach that is used to get value of goods particularly some NTFPs (Wunder *et al*., 2011). A non-traded commodity may locally be bartered for a marketed commodity. For example, NTFPs like wild mushrooms or fruits may not be traded in some places, but occasionally exchanged between households for rice, which is usually a high traded staple. Hence, rice can serve as the base for assigning value of the wild mushrooms or fruits. Therefore, rice can be used as common value measure that through triangulation implicitly set a price for wild mushrooms or fruits. Wunder *et al*. (2011)

explained that barter values are as good as direct trade in reflecting the real value of a particular good.

CHAPTER THREE

3.0 METHODOLOGY

3.1 Overview

The aim of this thesis is to enhance the understanding of the role of Non-Timber Forest Products (NTFPs) in climate change adaptation through studying households adjacent and distant to Iyondo Forest Reserve (IFR) in Kilombero District, Tanzania. This chapter links the analytical framework, discussed in chapter one, with the case study research undertaken in three villages in Kilombero District, Tanzania. In chapter one, four objectives were identified based on the gaps and contested issues in the literature, which formed basis for the following research questions: (i) How do households perceive climate change and its effects to livelihood security? (ii) What are the NTFPs status and their use under changing climatic conditions for households' livelihood adaptation? (iii) How economically valuable are the NTFPs in enabling households' livelihood adaptation? (iv) How are priority NTFPs and other strategies used to manage adverse effects of changing climate? This chapter is divided into three main sections. The first section describes the study area with focus on geographical location, climate, topography, soils, ethnography, and economic activities. The section further, describes vegetation in the area as well as the Iyondo Forest Reserve. The next section describes the data collection and analysis procedures. The proceeding section discusses limitations encountered in the course of this study.

3.2 The Study Area

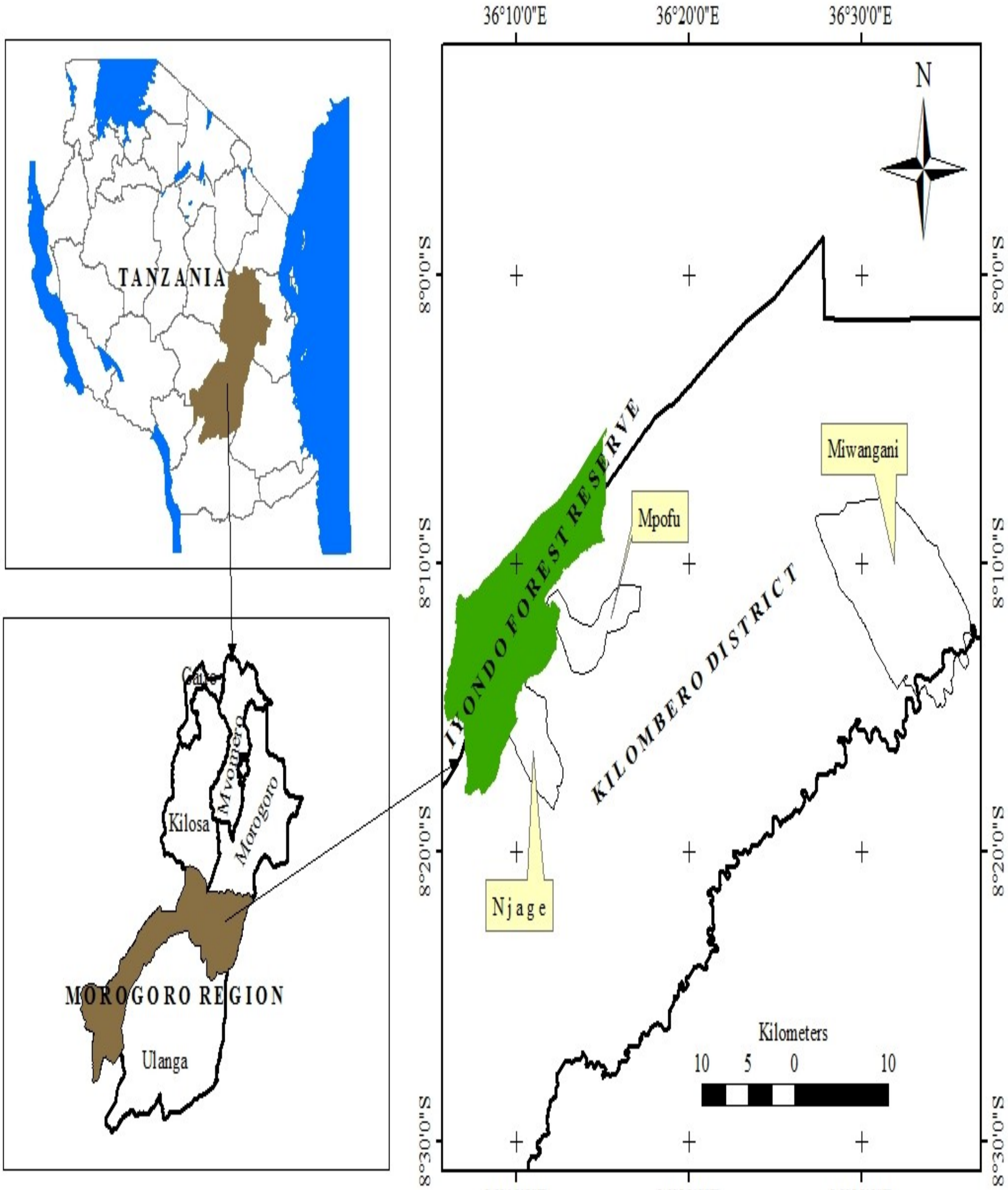
3.2.1 Choice justifications

Kilombero District is among the six districts of Morogoro Region (URT, 2013). A large part of Kilombero District is located in a floodplain area, which is important for main economic activities of the people including agriculture, livestock keeping, fishing and wild game hunting (Kato, 2007). However, these livelihood activities have been affected by the recurrent stresses due to changing climatic conditions including floods, dry spells during rainy season, extreme heat and some other stresses, which have adverse effects to the livelihoods of the people (Chamwali, 2000; Starkey *et al.*, 2002; Harrison, 2006). Specifically the study was conducted in three villages of Kilombero District namely Mpofu, Njage and Miwangani (Fig. 2).

The choice of the study area was based on villages that were highly affected by the changing climate stresses and in the same time adjacent to IFR (Lovett and Pocs, 1993; Harrison, 2006) with resources important for increasing resilience of the households against adverse effects of climate change. One of the villages (i.e. Miwangani Village) was distant to the IFR about 25 km away. Prior to sample village selection, a visit was done to six villages adjacent to IFR to establish proper sampling frame. During the visits, information collected included: proximity to the forest reserve, households' reliance on NTFPs from the forest, population size, land use and the effects of floods and dry spells to household's livelihoods. The study villages were finally chosen on basis of a set of criteria relating to the ability to respond to the research questions. Table 2 elaborates more on key selection criteria of the study villages.

Table 2: Key selection criteria for study villages in Kilombero District, Tanzania

Criteria	Reasons	Mpofu	Njage	Miwangani
Key climate impact on livelihoods and long experience with floods and dry spells for the past 30 years.	-To understand existence of local knowledge on changing climatic conditions and diverse ways used to manage the adverse effects such as use of improved crop varieties, changing cropping current, increases reliance on NTFPs, crop diversification and use of improved cropping technologies. -Memory of climate events and actions taken to cope, and barriers to success.	-Rain fed agriculture; the village is located highland and lowland areas, experiences floods in lowland areas. Dry spell is also experienced. -Main crops banana, maize sesame and cassava.	-Rain fed and irrigation agriculture, the village is located in lowland flood area, it experiences frequent floods and dry spells. - Main crops: rice, maize, cassava and banana.	-Rain fed agriculture, the village is located in lowland flood area, it experiences frequent floods and dry spells. -Main crops: rice, maize, sesame, and cassava.
Proximity to diverse natural resources (forest and wooded grasslands)	To understand role of diverse strategies to manage adverse effects of changing climatic conditions.	Yes (forest resources, crop farming and livestock keeping). Average of cultivated land size is 1.32 Ha	Yes (forest resources, crop farming and livestock keeping). Average of cultivated land size is 1.30 Ha	Yes (wooded grassland resources, crop farming). Average of cultivated land size is 1.77 Ha
Distance to main road and access to local markets for agricultural and forest products	To examine different strategies with differing distance to main markets and major roads	Near to main road and railway line (about 4 km) running from Ifakara to Mlimba Town.	Very near to main road and railway line running from Ifakara to Mlimba Town.	About 5 km to main road and railway line running from Ifakara to Mlimba Town.
Adequate infrastructure (access to study villages and availability of accommodation)	Ease of data collection within limited time	Road to village in good condition during dry periods, available accommodation at nearby villages Mbingu and Igima.	Road to village in good condition during dry periods, available accommodation at nearby villages Igima and Mchombe.	Road to village in good condition during dry periods, available accommodation at nearby villages Igima and Mchombe.



Source: NBS (2012)

Figure 2: Map showing location of study villages in Kilombero District, Tanzania

3.2.2 Geographical location

Kilombero District is located between 36° 04′ - 36° 41′ East, and 08° 00′ – 08° 16′ South, with elevation ranging from 262 to 550 m a.s.l. and covering 14 246 km^2. The District extends from the middle to far south-west of Morogoro Region. It is bordered with Morogoro Rural to the east and Kilosa to northeast. The north and west borders are shared by Mufindi and Njombe districts of Iringa and Njombe regions respectively, while at its south and southeast it shares the border with Songea - Rural (Ruvuma Region) and Ulanga District respectively. Large part of the district lays along Kilombero Valley a part of Rufiji Basin, which extends below the Udzungwa mountains from its east towards the south-west. The access to the study villages is through an earth road running from Ifakara Town to Mlimba; as well as the railway line of the Tanzania-Zambia Railway Authority (TAZARA) that extends from Dar es Salaam to Kapiri Mposhi (Hetzel *et al.*, 2008). The TAZARA line links agricultural potential areas in the south (including Kilombero District in Morogoro Region) with the Dar es Salaam port. Within the Kilombero District, there are railway stations along at Msolwa, Mang'ula, Kibelege, Ifakara, Ruipa, Mngeta and Mbingu. The road network is poor especially during rainy season, hindering access to important social services like health centres, schools and market places.

Two of the study villages are adjacent to IFR which covers 27 975 Ha. The reserve is part of Kilombero Nature Reserve (KNR) (URT, 2010c); other forest reserves constituting KNR are Kilombero West and Matundu. Iyondo Forest Reserve was declared in GN 555 of 19th December 1958 with a map Jb 432. The reserve is located between latitude 36º 06” – 36º 22” South and longitude 8º 00” – 8º16” 55 East. The altitude ranges from 300 to 600 m a.s.l. The reserve covers a hilly terrain along the base of the Udzungwa Mountains with Mgeta River on the western boundary, West Kilombero Scarp Forest Reserve on the north and Ruipa River on the east (Lovett and Pocs, 1993). Six villages namely Mbingu, Mpofu, Igima, Njage, Mchombe and Mngeta border the reserve.

3.2.3 Administration and population

Kilombero is one of the six districts of Morogoro Region. The other districts are Morogoro, Ulanga, Mvomero, Kilosa and Gairo. Kilombero District is administratively divided into five divisions, 23 and 97 registered wards and villages, respectively. According to the 2012 census, the district had a human population of 407 880 people of which males were 202 789 and females 205 091, with an average household size of 4.3 people (URT, 2013). This is equivalent to 27% change of the population from year 2002 to 2012. The growth rate in the district is estimated at 2.5% per year and it is projected to have 540 441 people in year 2025 (URT, 2013).

3.2.4 Climate, topography and soils

The climate in the study area is described as tropical to sub-humid favourable for human living. There are four main seasons that can be distinguished: - hot wet season from December to March, cool wet season from April to June, cool dry season from July to August, and hot dry season from September to November. The mean annual rainfall in the study area ranges between 1 200 and 1 800 mm, and is often not less than 1000 mm throughout the year. There are fluctuations between day and night temperatures as between seasons. The high temperatures are in the November and December months. The low temperatures are observed during the cool dry season, particularly in June when temperature may fall to as low as 12 ^{0}C. On the other hand, 38 ^{0}C can be recorded in November. However, normal temperatures range from 26 ^{0}C to 32 ^{0}C (Minja *et al*., 2001; Erlanger *et al.,* 2004; Hetzel *et al.,* 2007; 2008). The mean elevation in the study area ranges from 262 to 358 m a.s.l. (Table 3). The general topography is flat land with loam and sandy soil and some cotton black soil in flooded areas. In hilly areas, soils are sandy loam over crystalline rocks (Lovett and Pocs, 1993).

3.2.5 Ethnography

The study area is estimated to have more than 50 ethnic groups, but they still share similar livelihoods and socio-cultural norms due to type of natural resources present. The most dominant ethnic groups were Pogolo, Hehe, Ndamba, Nyakyusa, Bena, Ndali and Sukuma people. Specifically, the Hehe ethnic group was observed to dominate in both Mpofu and Njage villages. This is due to migration of people from Kilolo to Kilombero District because of reported better weather conditions for agriculture compared to places of their origin. People in Kilolo District used to have only one season of cultivation while in Kilombero District; there are about three seasons per year. Therefore, farmers claimed to have more harvests/yields from the same piece of land in Kilombero than in Kilolo. On the other hand, the dominant ethnic groups in Miwangani Village were Ndamba, Pogolo and Hehe.

3.2.6 Economic activities

The main economic activities in the study villages were agriculture livestock keeping, collection of NTFPs and causal labour. The main food crops grown include rice, maize, banana, cassava, fruits and horticultural crops (Kato, 2007). Rice is the key crop cultivated across the district, both as a food and cash crop, with Kilombero as a high volume contributor to total national rice production. Maize is grown primarily for subsistence purposes and as insurance for failed rice and banana crops or low market prices. Cash crops grown include: banana, cocoa, rice, sesame, groundnuts and sunflower. The Kilombero District has 400 000 hectares of a plain land suitable for agricultural activities such as farming, fishing and animal husbandry. According to its regional report in the National Sample Census of Agriculture (URT, 2012b), Kilombero had the largest area planted with paddy (80 207 ha 47%), the largest number of paddy growing households (56 925, 37%) and the highest yield (1.94 tons ha^{-1}) in the region. On maize production, the district had the fourth largest area (23 673 ha, 10% of the area planted with maize), with highest yield (1.45 tons ha^{-1}) in the region. Despite of good crop production in the study area, there are no organized markets, rather than traders buying the products directly either from the farms or through intermediaries.

3.2.7 Vegetation

The main vegetation found in the study area is Miombo woodlands, with some open grassland areas. Some of the dominant tree species with socio economic importance include; *Afzelia quanzensis* Welw., *Brachystegia microphylla* Harms, *B. spiciformis* Benth., *Combretum binderianum* (Kotschy) Okafa, *C. molle* (R.Br. ex G.Don)., and *Diplorhynchus condylocarpon* (Müll.Arg.), and *Diospyros mespiliformis* Hochst. ex A.DC. Others are; *Jubernadia globiflora* (Benth.) Troupin, *Terminalia sericea* Burch. ex DC., *Pericopsis angolensis* (Baker) Meeuwen, *Pterocarpus angolensis* DC, *Sorindeia madagascariensis* DC and *Tamarindus indica* L. (Lovett and Pocs, 1993). The Miombo woodlands extend from Kilombero District northwards up to Kilolo District. Vegetation in the floodplain is mostly covered by open grasslands. The most common grasses include *Vetiveria nigritana* (Benth) Stapf and *Hyparrhenia spp* (Kato, 2007; Laswai, 2011). On the farms, there are some planted trees and bamboos for timber, building pole, medicine, firewood and fruits. Planted trees include *Tectona grandis* L.f., *Senna siamea* (Lam.) Irwin et Barneby, *Azadirachta indica* A. Juss. and *Mangifera indica* (L.).

3.3 Methods for Data Collection

The purpose of this section is to present a bridge between research questions and appropriate methods for data collection based on theory knowledge. The choice of the methods was based on view of existing knowledge of the households as well as type of data needed to answer the research questions. Quantitative and qualitative methods were used to collect socio-economic and ecological primary data sets. Socio-economic data were collected through; focus group discussion (FGDs), cognitive mapping, semi-structured and structured questionnaire interviews, forest inventory and participant observations. Secondary data both published and unpublished literature from various sources was used to supplement primary data. Climatic data mainly rainfall and temperature from the Tanzania Meteorological Agency (TMA) for a span of 30 (1980 – 2010), and 20 (1990 – 2010) years, respectively were also used to supplement households perceptions on climate change in the study area. Table 3 summaries type of data collected based on research questions and key methodological choices.

Table 3: Linkages between research questions, theory and data needs

Research questions	Key methodological choices	Data needs
1. How do households perceive climate change and its effects to livelihood security?	• Understanding on insights to local historical occurrence of climatic stresses • Understanding on vulnerability context to households' livelihoods.	• Perceptions, knowledge and experiences on changing climatic conditions for the past 30 years • Empirical climate data to correlate with the local perceptions • Vulnerable livelihood assets
2. What is the NTFPs status and their use under the changing climate for households' livelihood adaptation?	• Link of changing climatic conditions on dynamics of vegetation • Climate change adaptation as a political process	• Places where NTFPs are collected • Counts of all plants • Name and uses of the NTFPs plant species • Available NTFPs in forest and wooded grasslands • Priority NTFPs important for managing climate stresses • Access to priority NTFPs
3. How valuable are the NTFPs resources to enable households' livelihood adaptation?	• Economic valuation of ecosystem goods and services • Knowledge on linkage of livelihood assets and outcomes • Local market structure and actors for NTFPs • Trend analysis on resource use	• Quantities of priority NTFPs collected annually at household level for subsistence and trade purposes • Unit value of each NTFPs • Factors influencing supply of the priority NTFPs in the study area • History on trend of use of priority NTFPs for subsistence and trade
4. How are priority NTFPs and other strategies used to manage adverse effects of changing climate?	• Link on livelihood capital assets and adaptation strategies • Livelihoods diversification for enhanced adaptive capacity • Adaptation as a societal transformation • Gender dimension in climate change adaptation	• Diverse ways to manage adverse effects of changing climatic conditions • Contribution of priority NTFPs to other livelihood capital assets • Income from other livelihood activities apart from NTFPs • Factors influencing adoption of climate stresses adaptation strategies
5. How are institutions influence households' access to priority NTFPs?	• Link livelihood capital assets with laws and policies governing access to the NTFPs	• Available local and formal institutions • Gender relation on access to NTFPs

3.3.1 Socio-economic data collection and analysis

Study design, sampling units and sample size

The study adopted a cross-sectional research design (Casley and Kumar, 1998), which enabled the researcher to capture more information from different cases at one time. According to Bryman (2012), a cross-sectional research design entails the collection of data on more than one case (usually quite a lot more than one) and at a single point in time in order to collect a body of quantitative or quantifiable data in connection with two or more variables (usually many more than two), which are then examined to detect patterns of association. The study employed purposive sampling to select study villages. According to Shively (2011) purposive sampling is undertaken when probability sampling is either not available for some reason or is deemed unimportant for the research outcome. In this study, two villages (*i.e.* Mpofu and Njage) out of six villages adjacent, with average distance ranging from one to five kilometres from IFR were selected for the study. Miwangani Village was also included in the sampled villages to represent households that are relatively distant with an average of 25 km to the IFR. The village is covered by wooded grasslands, which also contains some NTFPs that could enhance adaptive capacity of the people to changing climate effects. All selected villages had similar weather conditions.

Household was a sampling unit in this study. The household here is taken as the unit of analysis because it is where all decisions about production, investment and consumption are primarily taken (Thomson and Metz, 1998). A village register was used to select the households through assigning random numbers to each household. Then random selection was done from a list of random numbers to select sample households for questionnaire survey. A total of 215 households were randomly selected based on sampling intensity of 10% (Table 4).

Table 4: Sample size distribution in the study villages in Kilombero District, Tanzania

Village	Study strata	Number of households	Sampling intensity	Sample size (n)
Mpofu	Adjacent to IFR	714	0.1	70
Njage	Adjacent to IFR	868	0.1	87
Miwangani	Distant to IFR	581	0.1	58
Total		2 163		215

Pilot testing of the survey instruments was conducted to among 30 randomly selected households prior to implementation of the survey and then the questions were adjusted accordingly. Pilot testing was carried out in order to improve validity of the survey tools (Barribeau *et al.,* 2015).

Qualitative data collection

The study involved the following qualitative data collection methods: focus group discussion (FGDs), cognitive mapping, semi-structured interviews and participant observation. This combination of techniques helped to compliment limitations by one technique to allow cross checking and verification (triangulation) (Singleton *et al*., 1993).

Focus Group Discussions

These were conducted with groups of key informants at the village level with respect to their economic activities. Key informants were the people easily accessible, willing to talk and had great knowledge regarding the issues under discussion (Mettrick, 1993). Most of the people involved in the FGDs were selected households, Village Natural Resources Committee (VNRC) members, livestock keepers, village health officers, ward agricultural officers and distinguished elders with experience on climate induced effects and local adaptation. Two FGDs comprised of 10 - 12 people (Wong, 2000) aged from 18 years (as officially recognized as adult age) and above, where females and males were involved in each village. The aim of the exercise was to supplement information collected through other methods in a triangulation manner.

The FGDs adopted participatory techniques developed by Regmi *et al.* (2010) for assessing climate change effects and exploring adaptation options. The techniques used include resource mapping, climatic hazards mapping, trend analysis, vulnerability analysis, pair wise matrix scoring and ranking. During the first FGDs, the following information were collected: perceptions and experiences on climate change, vulnerable livelihood assets, vulnerability perception, availability of priority NTFPs, places where NTFPs are collected, access to priority NTFPs, as well as adaptation strategies addressing climate change effects (Appendix 1). Priority NTFPs were obtained during this exercise through pair wise matrix scoring and ranking (Appendix 5). While during the second FGDs, collected data were on past and current pattern of use of the priority NTFPs for subsistence and trade for managing adverse effects of climate stresses in the study area. Further, the factors influencing supply of NTFPs at household level were also discussed.

Cognitive mapping

This was used for community based vulnerability assessment to map households concepts through brainstorming (Downing and Ziervogel, 2004; Ziervogel *et al*., 2006; Locatelli *et al.,* 2008). Cognitive mapping applies to a group of methods for measuring mental representations. Cognitive mapping was conducted to a group of 15 villagers with diverse composition of men and women of different age classes. Community vulnerability and its variables were assessed based on the people’s perception and evidences. In cognitive mapping, each group in the study villages brainstormed about the different elements related to climate change vulnerability, and clustered them into exposure, sensitivity and adaptive capacity groups (Appendix 4). Finally, the group presented feedback in terms of the causal links between the climate change elements and explanations of these links.

Semi-structured interviews

Semi-structured interviews are guided conversations where broad questions are asked, which do not constrain the conversation, and new questions are allowed to arise as a result of the discussion (Bryman, 2012). The purpose of semi-structured interviews was to obtain information from an individual on climate change and livelihood issues. Semi structured questionnaire was based on written or memorized checklists (Appendix 2). The method was used to supplement to household information collected through structured questionnaire survey. This kind of interviews was conducted to key-informants from district to the village levels. The key informants were selected individuals among the surveyed households, organizations or leaders including Village Leaders, Village Elders (men and women), Village Natural Resources Committee members, Ward Leaders, in charge of health centres. Others were District Natural Resources and Forest Officers, District Agricultural Officer, District Health and Meteorology Officers. Data obtained through this method-supplemented data collected through FGDs and structured interviews. The following information were also collected: knowledge and experiences on climate change and variability, vulnerable livelihood assets, availability of the priority NTFPs as well as adaptation strategies developed.

Participant observation

Participant observation has been explained by Bryman (2012) as that research in which the researcher immerses him- or herself in a social setting for an extended period of time, observing behaviour, listening to what is said in conversations both between others and with the fieldworkers, and asking questions. The tool also assists the researcher to clarify some misunderstandings that occur if the households provide information that does not contest with the actual situation, and reduces the number of questions that are needed to be asked (Jackson and Ingles, 1998). Through this method, a researcher obtained more inside experience of many issues that households are doing in their daily routine.

The researcher spent more than 6 months with the households (with some breaks) working with them, participating in meetings and social gatherings. Participant observation was designed in such a way that, it covered all the four climatic seasons as described under Section 3.2.4. The researcher spent about three weeks in each season, to understand better on their perceptions of climate change, availability and use of the NTFPs, vulnerable livelihood assets and adaptation strategies developed to address the resulted effects across the different seasons.

Quantitative data collection

Structured questionnaire interviews

A structured questionnaire interview is a quantitative research method commonly employed in social survey research (Bryman, 2012). The aim of this approach is to ensure that each interview is presented with exactly the same questions in the same order. This ensures that answers can be reliably aggregated and comparisons can be made with confidence between sample subgroups or between different survey periods (Bryman, 2012). Structured questionnaire interviews were conducted by administering a household questionnaire, with both closed and open-ended questions to sample households (Appendix 3). Contrary to close-ended questions, open-ended questions accommodated respondents' ideas and opinions through free explanation. The questionnaire was designed to get information on socio-economic activities, the individuals' understanding and perception on climate change and variability, availability and access to NTFPs, use, vulnerable livelihood assets, adaptation strategies developed, factors influencing availability of priority NTFPs at household level. During the survey, quantities of priority NTFPs collected at household level were recorded based on respondents' perceptions and field measurements.

Socio-economic data analysis

Qualitative data analysis

Qualitative data collected through FGDs were subjected into content analysis. Stemler (2001) defined content analysis as a systematic and replicable technique for compressing many words of text into fewer content categories based on explicit rules of coding. In other words, content analysis is a set of methods for analyzing the symbolic content of any communication. The basic idea is to reduce the total content of communication to some set of categories that represent some characteristics of research interest (Singleton *et al*., 1993). Through this method, the data collected using verbal discussions with key informants were analyzed in details whereby the recorded dialogues were individually broken down into smallest meaningful units of information or themes and tendencies. Qualitative data were used along with the output generated from quantitative data to triangulate and enrich the understanding on the role of NTFPs resources in enhancing adaptive capacity to households against experienced climate change adverse effects.

Community based vulnerability assessment data collected through cognitive mapping were analysed right in the field with guidance of the households. The analysis was carried out using the key variables: exposure (E), sensitivity (S) and adaptive capacity (A). The variables were ranked into four levels based on community perception and the numerical values (indices) were used in the Equation 1 (Metzger *et al*., 2006).

$V = E \times S \times (1/A)$ ....(1)

Where;

V = Vulnerability

The vulnerability indices were interpreted as follows (Vincent, 2004);

1 – 1.4 = Low;

1.5 – 2.4 = Medium;

2.5 – 3.4 = High and

≥3.5 = Very high

The numerical vulnerability indices were used as basis for comparison of the vulnerability indicators in each parameter for each variable. Exposure based on local climate change perception included parameters such as temperature, rainfall, plants/animals behaviour changes, disasters, livelihood activities and other physical information. Community sensitivity based on effects of climate change at local level included parameters such as agriculture and food security, forest and biodiversity, settlement and infrastructure, water and energy as well as human health. Adaptive capacity was assessed based on livelihood assets both human resource, natural, social, financial and physical.

Quantitative data analysis

Quantitative data collected from structured household questionnaire survey were summarized, coded, and subjected to the Statistical Package for Social Sciences (SPSS) computer software tools for data analysis. Both descriptive and inferential statistical analyses were carried out. Descriptive statistical analysis included measures of central tendencies (such as means), as well as measures of spread/variability (such as ranges, standard error) and summarize data into frequency distribution tables, and percentages.

Chi square test (χ^2) was used to determine whether there is significant association between categorical variables across households adjacent and distant to IFR. Inferential data analysis was carried out using multinomial logistic regression analyses to explore causal relationship between socio-economic variables influencing adoption of developed climate change adaptation strategies.

The economic value of priority NTFPs collected for a period of one year was obtained. Values of the selected priority NTFPs were calculated from the data on the annual quantity and unit value obtained through questionnaires information. The quantity of each product was multiplied with market price. According to Tietenberg and Lewis (2012) market price is an approach that is used to value environmental goods and services that have established markets.

The following discounting formula (Equation 2) was used to estimate the economic value of NTFPs that was expressed in terms of annual present value (PV):

$$PV = a[(1+r)^n - 1]/[r(1+r)^n] \qquad \ldots\ldots\ldots\ldots(2)$$

Where:

PV = present value of NTFPs in TZS

a = is the annual value of NTFPs in TZS

r = social discount rate. The discount rate was useful in this study because the study dealt with benefits of the forests and woodlands, which are public property and attached with community values that count more than individual preference. Therefore, the social discount rate chosen was 10%, which is recommended by the World Bank (Monela *et al.,* 2005).

n = time horizon

Assuming continuous flow of benefits to the community from the forest and woodlands for infinite annual series, then 'n' in equation (2) above appropriate infinity and a useful formula becomes (Equation 3):

$$PV = \left[\frac{a}{r}\right] \qquad \text{...(3)}$$

Variables as defined in equation (2).

From equation 3, the annual value 'a' was calculated as given in Equation 4;

$$a = Q_m * V_u * P_r * H_t \qquad \text{...(4)}$$

Where:

Q_m = mean annual quantity of NTFPs consumed per household

V_u = unit value in TAS per unit measure

P_r = proportions of respondents using the product in percentage

H_t = total number of households (8 308) in the study area

In calculating economic values of NTFPs, the following key assumptions and considerations were adhered:-

(i) Assumed that, all NTFPs collected were traded.

(ii) Economic value of NTFPs was in terms of gross values because estimation of cost of harvesting of each NTFP separately seemed very involving.

> This is because of the nature of trips into forest and woodlands, which were multipurpose, like doing it along with farming activities, and some of the NTFPs were collected jointly, so estimating them could lead to double counting. According to Morse-Jones *et al.* (2011), double counting may occur where competing ecosystem services are valued separately and the values aggregated; or, where an intermediate service is first valued separately but also subsequently through its contribution to a final service benefit.

The multinomial logistic regression analysis was used to analyse the socio-economic factors influencing adoption of developed climate change adaptation strategies. The multinomial logistic regression is an analytical approach that is commonly used in adoption decision studies involving more than two multiple choices (Green, 2000). In this case, there were three categories: households without adoption strategies; households with one up to three strategies and lastly households with more than three strategies. The approach is also appropriate for evaluating alternative combinations of adaptation strategies, including individual strategies. The following multinomial logistic regression equations (5 and 6) were used:

$$\text{Log}\ [P(\text{adoption1-3 strategies}/(1-P(\text{no-adoption})))] = \beta 0 + \sum \beta_i X_i + \varepsilon_1 \ldots\ldots\ldots\ldots\ldots\ldots\ldots (5)$$

$$\text{Log}\ [P(\text{adoption}>3\ \text{strategies}/(1-P(\text{no-adoption})))] = \beta 0 + \sum \beta_i X_i + \varepsilon_1 \ldots\ldots\ldots\ldots\ldots\ldots\ldots (6)$$

Where;

P = probability function that a household adopts 1-3 strategies or more than 3 strategies

(1-P) = is the probability that a household does not adopt to any strategies

β_0 = constant term of the model without the independent variables

β_s = are parameter estimates for the independent variable, X

ε = is an error term which represents unobservable factors assumed to be independently distributed over the survey period;

X = is a vector of socio-economic factors, which include.

Age (X_1) – this is a continuous explanatory variable measured from the age of respondent. Studies show presence of relationship between age of household head and adaptation (Dolisca *et al*., 2006; Tazeze *et al*., 2012).

Household size (X_2) – this is a continuous explanatory variable that was measured from number of members of the respondents' household.

Education level (X_3) – is a dummy explanatory variable, which was given 1 to denote respondents with formal education (primary, secondary, college and university) and 0 for otherwise. Educated and experienced head of households are expected to have more knowledge and information about climate change and agronomic practices that they can use in response.

Residence period (X_4) – this is a continuous explanatory variable that was measured from number of years the respondent has lived in the study area. Duration a household head spent in the area for living was related to increased experience about the area. This included gained knowledge and information about agronomic practices and climate change.

Land ownership (X_5) – is a binary explanatory variable that was given 1, when respondent declared to own land and 0 for otherwise.

Household income (X_6) – this is a continuous explanatory variable that was measured from the annual total household income. The annual income was estimated mainly from agriculture, formal employment, petty business, casual labour, sales of NTFPs, livestock and remittances.

Forest access rules (X_7) – this is a binary explanatory variable that was given 1, when respondent declared that rules and regulations enable access to forest products and 0 for otherwise.

3.3.2 Ecological data collection and analysis

Sampling design and data collection procedures

The study adopted systematic sampling design in order to cover large area of the Iyondo Forest Reserve. This ensured an even spread of the samples throughout the forest reserve, therefore being able to observe all NTFPs resources available. Collection of ecological data involved NTFPs resource assessment through forest inventory, employing concentric sample plots established along transects. The design was adopted from the Asia Network for Sustainable Agriculture and Bio-resources (ANSAB) (2010) with some modifications on plot size. The ANSAB (2010) approach was adopted because it solely deals with inventory of NTFPs for tropical forests. A total of 46 plots each with radii of 3 m, 6 m, and 13 m were laid out along six transects with a sampling intensity of 0.01%. Table 5 shows type of data that were collected in each plot radii. The initial location of transects and the first sample plot was located at 50 m from the forest boundary, using a Global Positioning System (GPS). Subsequent sample plots were located systematically at 200 m interval along transects, while the distance between transects was 1.5 km.

Table 5: Sub plots size and type of data collected in Iyondo Forest Reserve, Kilombero District, Tanzania

Sub-plot size Radius (m)	Area (ha)	Data collected
3	0.003	Shrubs, herbs and regenerants (dbh <5 cm) counted
6	0.011	All trees with dbh ≥5≤20 cm counted and measured dbh
13	0.053	All trees with dbh >20 cm counted and measured dbh

During NTFPs resource inventory, two local field guides, and a botanist from Tanzania Forestry Research Institute (TAFORI) Herbarium in Lushoto were involved in identification and marking of all NTFPs in each study plot. Among other activities, the local field guides had a role of identifying and marking all NTFPs that were reported during FGDs and key informant interviews sessions. Although the botanist was highly skilled and experienced, in plant identification, the two local field guides were also used to aid identification process (URT, 2010d). Plant specimens, which could not be assigned botanical names directly in the field, were collected, pressed and taken to TAFORI Herbarium in Lushoto District for identification. The following information were collected in each sample plot: counts of all plants, diameter at breast height (DBH) (cm) of tree species, regenerants of the tree species, name and uses of the NTFPs plant species (Appendix 6).

Ecological data analysis

In the context of this study, number of stems/seedlings ha^{-1} (N) was of interest parameter in analysis. The number of stems/seedlings ha^{-1} (N) was computed based on Philip (1994) using the following formula (Equation 7):

$$N = \frac{\sum \frac{n_i}{a_i}}{n} \qquad (7)$$

Where;

n_i = tree or seedlings counts in the *inth* plot

a_i = area of the *inth* plot in hectares

n = number of sample plots

N = number of stems/seedlings per hectare

3.3.3 Climate data collection

Climatic data mainly rainfall and temperature were collected from the Tanzania Meteorological Agency (TMA) for a span of 30 (1980 – 2010), and 20 (1990 – 2010) years, respectively. The data were used to supplement household's perceptions on changing climatic conditions including global climate change in the study area. Information on individual's perceptions on climate change, vulnerable livelihood assets, access and use of NTFPs, and adaptation strategies developed was reviewed.

3.4 Limitations of the Study

(i) The occurrence of floods in 2013 made the road from Ifakara Town to the study area not passable; therefore delaying data collection process on scheduled time. This made the researcher to compensate such loss of working days by securing more days to cover the delayed time.

(ii) The study did not have access to daily weather data, thus limiting analysis of daily shift of climatic condition. Daily weather data were important in this study particularly when analyzing daily trends of climatic conditions. For example, for the case of rainfall data, this information could also show us the number of days with and without rains in a month. It was important to understand such information, as agricultural crops are sensitivity to amount of moisture in the soil during the course of growth. However, the study used monthly data based to present the trend of rainfall and temperature in the study area.

(iii) Presence of fierce large wild animals like elephants and leopards in some areas in the Iyondo Forest Reserve threatened life of the research team and as well as smooth continued ecological data collection. To overcome such a situation a game officer with a gun was hired to accompany the research team.

(iv) Some of the respondents during household survey did not recall well the climatic conditions for the past 30 years. To overcome the problem of recall, the study collected climate data from the Tanzania Meteorological Agency (TMA) as well as information from FDGs that were used to triangulate the households' climate perception data.

(v) The data on annual collection of priority NTFPs for subsistence use and trade are limited to one year. It was difficult for individuals to memorise the amount of priority NTFPs collected for the past two years and beyond. It was possible to capture trends over time through qualitative information obtained during FGDs and from key informants. During FGDs, participants were requested to recall whether collection of NTFPs for subsistence and trade was increasing or decreasing. Qualitatively the trend showed increasing collection of priority NTFPs for both subsistence and trade. This information was useful for triangulation with the annual data collected during household survey.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Overview

The aim of this thesis is to enhance the understanding of the role of Non-Timber Forest Products (NTFPs) in climate change adaptation through studying households adjacent and distant to IFR in Kilombero District, Tanzania. The chapter brings together empirical findings which are divided into four sections based on specific objective outlined in chapter one. The first section present findings on households' perceptions on effects of changing climatic conditions to their livelihoods. The second section present results on availability and use of priority NTFPs under the current change in climate in the study area. The third section give findings on economic value of selected priority NTFPs under the changing climatic conditions. The section further discusses factors influencing collection of NTFPs at household level. The forth section present results on current roles of selected priority NTFPs and other local adaptation strategies used by communities to cope with effects of climate change in the study area. The section is sub-divided into other three sub-sections that include role of priority NTFPs resources for livelihood adaptation; other developed local adaptation strategies and socio-economic factors influencing adoption of local climate change adaptation strategies.

4.2 Perceptions on Changing Climatic Conditions

Households adjacent and distant to IFR had different perceptions on changing climatic conditions to the livelihood assets. In the context of this study, the households' perceptions on changing climatic conditions were related to the following aspects: climate induced events, locally perceived climate and vulnerable livelihood assets.

4.2.1 Climate induced events

During FGDs, households mentioned climate induced events that occurred from 1973 to 2013 in the study area (Table 6). In the context of this study, climate induced events such as dry spells, floods, pests and diseases were understood as the events that are directly or indirectly caused by climate related shocks and stressors. It was observed that before 2000, most of the recorded climatic events seemed not to occur in each year; meaning there were good and bad years. One of the key informants in Mpofu Village adjacent to IFR reported that:

" ………the current years are not good because the rains we receive is insufficient to support crops to grow, that is the rains come but crops do not do well as it was in the past in 1980s, we now have to add fertilizers to have better crop yields ".

Table 6: Climate induced events that occurred between 1973 and 2013 in Kilombero District, Tanzania

Climate induced events	Year of occurrence	Frequency
Dry spells	1973, 1977, 1981, 1998, 1999, 2012	6
Floods	1982, 1984, 1986, 1998, 1999, 2011, 2013	7
Cholera	1973, 1986, 1998, 2010, 2011	6
Malaria infections	1987-2013	recurrent
Outbreak of grasshoppers (*Zonocerus variegatus* L.)	1996, 1999, 2000, 2009, 2010, 2011, 2012, 2013	8
Outbreak of locusts (*Nomadacris septemfasciata)*	1977	1
Outbreak of army worms (*viwavi jeshi*)	2005, 2009, 2010, 2011, 2012	5
Outbreak of Rice Yellow Mottle Virus (RYMV) disease *(Kimyanga*)	2012, 2013	2

From the key informant quotation, it was understood that, because of frequent floods top soils have been eroded leaving agricultural land unfertile, which requires farmers to improve soil nutrients with organic or inorganic fertilizers. It was further argued that from 2000 almost each year there were certain adverse climatic events occurring. This showed that, households have been hit more by adverse climatic stresses now than they used to. The stressors were found to occur as a single event in a year, or multiple events in the same year. For example, stresses like pests and diseases were more prominent during dry spell periods than during rainy seasons.

Therefore, in prolonged dry spells period most of the crops particularly the dominant food crops (rice and maize) become more susceptible to pests and diseases like the grasshoppers and armyworms. Unpredictable rainfall, declining soil fertility, and increased incidence of some pest and disease are leading to more frequent crop failure and increased yield variability. The outbreak of Rice Yellow Mottle Virus (RYMV) disease *(kimyanga*) is an example of plant diseases reported. To adapt with food shortage, households are being educated on how to cultivate different varieties of crops especially those, which mature early and are tolerant to dry spells as well as pest and diseases (Shemsanga *et al.,* 2010).

The findings in this study indicate that occurrence of climate induced events to both households adjacent and distant to IFR is increasing year after year with only exception to locusts (*Nomadacris septemfasciata*) that only occurred in 1977. Although occurrence of the insect has been reduced, but frequency of new insect, the grasshopper (*Zonocerus variegatus* L.) is high.

According to the IPCC Firth Assessment Report (Niang *et al.,* 2014,) drought stress in most of the developing countries particularly in Africa is induced by decreasing precipitation, which is likely to perpetuate in future years. Generally, this indicates changes in climatic conditions that favour survival of certain species in a particular locality. For climatic induced events with increasing frequency, it is important to raise awareness to households on developing effective and sustainable coping strategies particularly use of NTFPs that could be used to address different livelihood capital assets in order to build their adaptive capacity.

4.2.2 Households' perception on climate change

The majority of households adjacent and distant to IFR perceived the climate of their area to have changed as indicated by increase in amount of rainfall, delay in onset of rain with high intensity and for short time and temperature increase in the area (Table 7). The households' perception on climate change did not differ significantly ($P \leq 0.05$) in all assessed climate attributes. This implies that, both households adjacent and distant to IFR are similarly affected by climate change.

Table 7: Households' perception on climate change in Kilombero District, Tanzania

Aspects	Attribute	Responses (%) HHs adjacent to IFR (n = 157)	HHs distant to IFR (n = 58)	χ^2	P value
Rainfall amount	Increasing	67	72	6.191	0.342Ns
	Decrease	29	24	4.395	0.941Ns
	No change	7	3	0.505	0.681Ns
*Rain season	Delay in onset of rain season	77	93	2.709	0.295Ns
	Early cessation of rain season	35	38	5.060	0.255Ns
Rainfall intensity	High rains for short time	65	56	2.318	0.957Ns
	Little rains for long time	26	17	5.353	0.148Ns
	Little rains for short time	12	9	0.539	0.734Ns
Temperature	Increase	71	83	4.632	0.759Ns
	Decrease	22	13	2.284	0.626Ns
	No change	5	9	0.929	0.281Ns

*Multiple response analysis was applied to rain season variable; HHs = Households; Ns = Non significant at $P \leq 0.05$; χ^2 = Chi-Square value

Focus group discussion noted that in the past (1990s to 1970s) the rainy season started in October, but currently not as stable as before. The majority of participants noted that rains sometimes start either in mid-December or early January, a situation that has forced them to change cropping calendar and system. One of the respondents in Njage Village during questionnaire survey explained that:

" as currently rains are starting late, we are sowing seeds before tilling so that when it comes the seeds are already in the soil, unlike the past (1990 to 1980s) where we tilled the land as a way of reducing weeds because they grow fast soon after the rains. This system to us is not good because it increases the costs for weeding as we sow seeds before weeds have come out".

Similarly, the first rain season cessation was mentioned to be earlier than it was in the past two decades (1990s to 1980s). These two perceptions were consistent with the perceived shorter rainy season in all study sites. The shorter rain season resulted into reduction in crop yields because some of the crops failed to mature. The current findings are in line with those by Urama and Ozor (2011) in the Western and Central Africa where they revealed a decrease in length of the growing season and yield potentials due to climate change, thus called for advocated agricultural innovations for adaptation.

In the forest sector, increased temperatures are predicted to extend or shorten the growing season of some NTFPs producing species (Cowie, 2007; Ravindranath, 2007) such as those, which produce fruits, mushrooms and wild vegetables, therefore altering yields. To maintain availability of these products to households, it is important to develop improved technologies for processing and storage of various NTFPs like medicinal plants, fruits and mushrooms. These technologies could be promoted to households to increase their adaptive capacity to adverse effects of climate change.

Climatic hazards such as increasing rainfall amount as well as its intensity was reported to cause floods on agricultural fields, impacting the livelihood of both households adjacent and distant to IFR (Table 8) and mostly to the Miwangani village which is located on lower elevation level compared to Mpofu and Njage villages. Houses and roads were also reported to be destroyed by floods in all villages therefore increasing the number of homeless households and disconnecting communication especially access to social services such as hospitals and schools.

Table 8: Effects of changing climate conditions to households' livelihoods in Kilombero District, Tanzania

Aspects	Responses (%)		χ^2	P value
	HHs adjacent to IFR (n = 157)	HHs distant to IFR (n = 58)		
High risk of floods on agricultural fields	98	99	12.884	0.420Ns
Wilting of crops due to moisture stress	81	72	9.628	0.318Ns
Settlements destructions due to floods	11	20	5.369	0.204Ns
Increased outbreak of human diseases	7	21	9.207	0.032*
Increased outbreak of pests and diseases in crop and livestock	31	17	11.298	0.013*
Drying of rivers and dams due to dry spells	16	11	4.578	0.224Ns
Increased wild fires on forests and grasslands in prolonged dry season	7	3	4.923	0.404Ns
Roads destructions due to floods	6	2	5.525	0.137Ns

The response (%) is a result from multiple responses analysis; HHs = Households; Ns = Non significant; *= Significant at P≤0.05; χ^2 = Chi-Square value

Increased temperature was reported to cause moisture stress on crops as well as increase in outbreaks of both animal and plant pests and diseases. The majority of the interviewed respondents adjacent (81%) and distant (72%) to IFR reported crops to have been wilting due to moisture stresses, thus reducing crop yields. Moisture stresses has also been related to outbreak of army – worms (pests) as well as Rice Yellow Mottle Virus (RYMV) disease in rice crop. Results on increased outbreak of human, crops and livestock pest and diseases differed significantly (P≤0.05) among households adjacent and distant to IFR. The findings imply that the outbreak level and frequency of the pest and diseases is not constant across the strata, probably due to different elevations that might have effect on its biological coverage. Note that, Mpofu and Njage villages are relatively located in higher elevation that Miwangani Village.

Results from this study concur with observations by Akponikpe *et al.* (2010) in West Africa and Sanga *et al.* (2013) in Pangani River Basin and Pemba in Tanzania, where moisture stress was a fundamental cause of susceptibility of the crops to other stresses like pests and diseases, leading to reduced crop yield. According to Allarangaye *et al.* (2006) and Michel *et al.* (2008), RYMV is the most important virus disease for rice in Africa, which reduces paddy productivity.

Increased temperature was also related to increased dry spells during rainy season, which caused rivers, streams and dams to dry up, hence water shortages to people (Table 8). The shortage of water at household level in the study area was claimed to be the source of outbreak of human diseases such as diarrhoea, typhoid, dysentery and amoeba. It was also noted that, cholera occurred more during periods of floods due to increased rate of germs that cause the disease. Similar observations have been pointed out by Traerup *et al.* (2010) where high rate spread of waterborne diseases in Tanzania may be boosted by extreme climate conditions that enable the disease vectors spread more easily. Other human diseases that were reported to be associated with increased temperature in the study area included malaria, skin rashes, tick borne diseases and diarrhoea.

In the study area, households adjacent and distant to IFR reported to rely mostly on medicinal plants as immediate remedy especially during flooding as roads to health centres were not passable. However, in some cases when accessibility to health centres was fine, some of the people were not able to afford modern health service costs. This implies that, the use of medicinal plants for health care will continue as far as climate induced events and costs for modern health services will persist. Therefore, use of NTFPs could be promoted with emphasis on value addition coupled with making the resource available and used sustainably.

The households' perceptions on changing climate have been supported by existing empirical data from the Tanzania Meteorological Agency (TMA). The empirical data showed that rainfall and temperature in the study area have been unpredictable (Fig. 3 and 4). The recorded trends also act as baseline information that is important for future climate change monitoring in the study area.

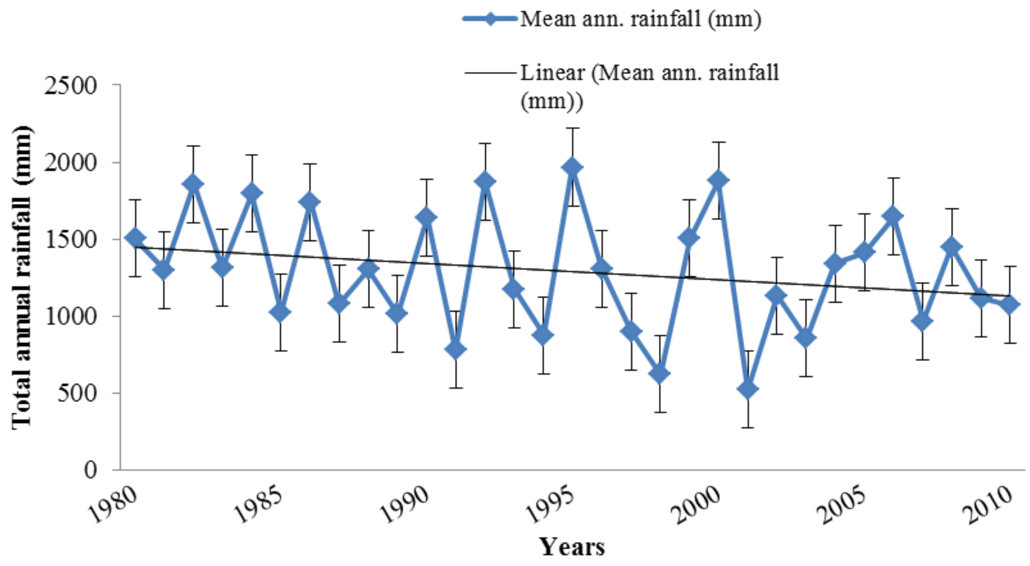


Figure 3: Mean annual rainfall (mm) recorded between 1980 and 2010 in Kilombero District, Tanzania.

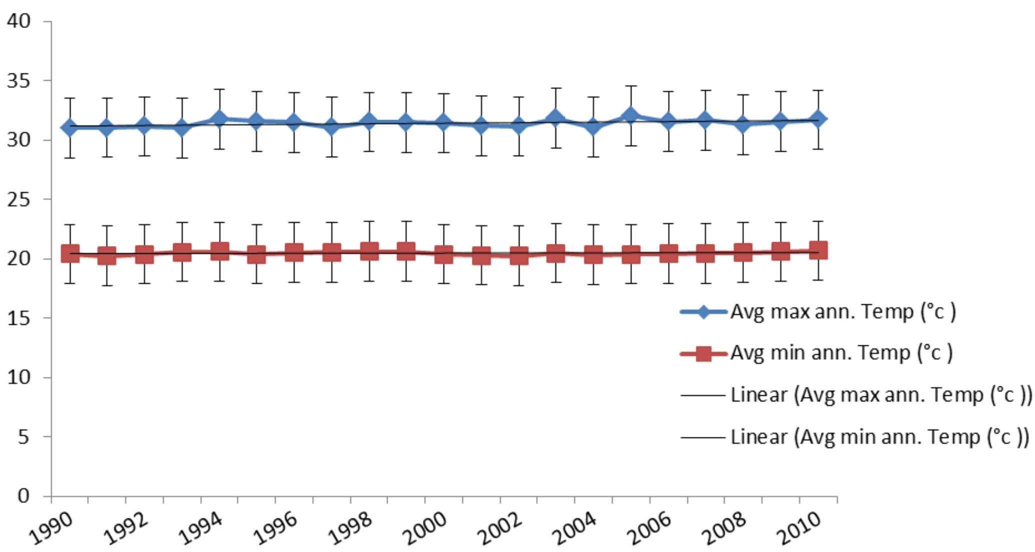


Figure 4: Average maximum and minimum temperature (°C) recorded between 1990 and 2010 in Kilombero District, Tanzania.

The rainfall pattern from 1980 to 2010 showed a trend of decrease in total rainfall received for the past three decades. This implied that the study area has been receiving high rains for short periods, as was perceived by the majority. Furthermore, temperature trends have indicated relatively increase in both maximum and minimum average annual temperature, in the study area over the past decades, implying prolonged dry spells in the area. The prolonged dry spells especially during rainy season could increase chance for termites to attack crops, construction materials such as thatch grass, withies and ropes and in turn, collection of construction materials from the wild increases hand in hand with reduced overall productivity at household level.

The increase in termite attack has been associated with climate change-induced dry spells (Sileshi *et al*., 2009). Prolonged dry spells were also reported to affect forests and grasslands due to increased wildfires. Wildfires were reported to be a serious threat in Njage village forest as well as in the grasslands in Miwangani and Mpofu villages. For example, respondent adjacent to IFR reported that the reserve was much vulnerable to wildfires especially in the dry season. Livestock, mainly cattle and local chicken were reported to be vulnerable to both prolonged dry spells and frequent floods due to scarcity of feeds and pastures.

The Fourth Assessment Report of the IPCC (Rosenzweig *et al.,* 2007) noted similar observations where extended warm periods and increased droughts led to increase in water stress in forests and grasslands and increased frequency and intensity of wildfires. According to Khandlhela and May (2006), poor quality of pastures due to floods and dry spells increased vulnerability of cattle and goats to pests and diseases, thus causing deaths of the livestock in Limpopo Province, South Africa. The cited literature support findings from the current study as the recorded adverse events due to changing climate are similar to those reported elsewhere in Africa.

4.2.3 Households' vulnerability to changing climatic conditions

Vulnerable livelihood assets

Based on the reported adverse effects of changing climatic conditions including climate change in the study area, the following livelihood assets were found to be vulnerable: natural, physical, human and social (Table 9).

Table 9: **Response on livelihood assets vulnerable to changing climatic conditions in Kilombero District, Tanzania**

Aspects	Responses (%)		χ^2	P value
	HHs adjacent to IFR (n = 157)	HHs distant to IFR (n = 58)		
Natural	100	97	6.060	0.457Ns
Physical	29	23	4.632	0.836Ns
Human	9	11	3.711	0.136Ns
Social	2	3	4.338	0.214Ns

The response (%) is a result from multiple responses analysis; HHs = Households; Ns = Non significant at $P \leq 0.05$; χ^2 = Chi-Square value

The majority of respondents adjacent (100%) and distant (97%) to IFR reported that natural capital asset particularly agricultural farms were the most vulnerable to adverse effects of changing climatic conditions and its effects. In particular, lowlands in the study area, which are used for agriculture, were much affected by floods, as during flooding the land does not support growth of some of the crops including maize and some legumes. Other natural capital assets claimed to be vulnerable to changing climatic condition were woodlands and grasslands due to wildfires. Frequent flooding also causes sheet erosion, which removes all top soils leaving unfertile soils. Furthermore, flood increases production costs as people are forced to use inorganic fertilizers to enrich soils for high productivity. This increases vulnerability to some social groups who do not have ability to buy inorganic fertilizers.

Dry spells also were reported to increase vulnerability to natural capital assets particularly farms, rivers and natural ponds and forest. All households in the surveyed areas were victims of the dry spells, which affected crop productivity as planted crops dried before maturity (Plate 1). The most affected crops in lowland were paddy and maize while for upland were maize and banana. The study witnessed wilted banana plants due to lack of sufficient water. Similarly, rivers and natural ponds were vulnerable to dry spells, as water level reduced and some become seasonal. It was reported that rivers and natural ponds not only provide water for domestic use to households but also is a place where fishing activity takes place. Different social groups benefited from the rivers and dams especially vulnerable ones like elder people and widows who were reported to have less diverse sources of income.

Plate 1: Drying up of maize crop before maturity due to dry spells that occurred in 2013 at Miwangani Village, in Kilombero District, Tanzania.

Dry spells also made forests and grasslands vulnerable to wildfires. For example, respondents adjacent to IFR reported that the IFR has been much vulnerable to wild fires especially in dry season. Wildfires were reported to be much threat in Njage village forest as well as in the wooded grasslands in Miwangani and Mpofu village. Livestock, mainly cattle and local chicken were reported to be vulnerable to both prolonged dry spells and flooding, due to scarcity of feeds and pastures. The findings from this study are similar to those by Khandlhela and May (2006), who noted that, poor quality of pastures due to floods and dry spells increased vulnerability of cattle and goats to pests and diseases, thus causing deaths in Limpopo Province, South Africa.

The other livelihood assets that were observed to be vulnerable to floods are the physical asset, which included roads, and houses. It was reported that floods of 1998 eroded part of the road that connect study villages to Ifakara Town. Similarly, the floods of 2014 in March and April affected the roads and there were no connection to nearby villages and Ifakara Town (Plate 2). Such situations affected households to access social services such as hospitals, market places, railway station, police station, and nearby villages. Flooding also posed a threat on peoples' houses with considerable number of houses in lowland being destroyed and people lost valuable properties.

According to URT (2012a) in April 2011, floods in Kilombero valley destroyed about 663 houses and submerged 2942 others, which made 9000 people homeless. The same report revealed that food stores, farms and other infrastructures were destroyed and approximately 2256 hectares of crops including paddy and maize were as well destroyed. Most of the houses in the study area were built of poles and mud, therefore becoming most vulnerable to floods and termites attack effects.

Plate 2: Part of main road that connects study villages (Miwangani, Mpofu and Njage), Ifakara Town, and other nearby villages which was affected by floods in 2014.

Human capital assets were also claimed to be vulnerable to climate change due to increased temperatures causing drying of some rivers and ponds that were sources of water for domestic household use and fish. The shortage of water for domestic use perpetuates outbreak of human diseases like dysentery, typhoid, amoeba and skin rashes.

Increased temperatures was also claimed to favour survival of mosquitoes in cool seasons from June to August. It was reported that, two decades ago during such period, mosquitoes were few and therefore reduced malaria incidences.

The situation is different now, as malaria incidence is equally the same throughout the year. With such situation, human capital asset is affected much resulting into reduced work force to pursue different livelihoods strategies. On the other hand, social capital assets were also vulnerable to climate change in such a way that during incidences of extreme events, households failed to participate fully in some social events including entertainment, attending meetings of various groups and social networks.

The social capital assets under climate change include understanding emotional and psychological needs of the people. According to IPCC Firth Assessment Report (Noble *et al*., 2014) extreme events such as floods, dry spells and wildfire can lead to mental suffering resulting in the need for psychological support and counselling. Similar observations were reported in revealed in the current study.

Climate change vulnerability index in the study area

Climate change vulnerability index in the study area was revealed to be very high to households distant to IFR (Vulnerability Index = 4.0) compared with those adjacent to, which had average Vulnerability Index of 3.25. The vulnerability in the study area was expressed in terms of exposure, sensitivity and adaptive capacity (Table 10). The high vulnerability index to households distant to IFR implies that, these households are highly exposed and sensitive to climate change adverse effects.

Table 10: Climate change vulnerability index in Kilombero District, Tanzania

Elements of vulnerability	Score index	
	HHs adjacent to IFR	HHs distant to IFR
Exposure	2.82	3.11
Sensitivity	2.52	2.87
Adaptive capacity	2.21	2.23
Vulnerability index	3.25*	4.0**

*High vulnerability; **Very high vulnerability; HHs = Households

The high vulnerability to the households distant to IFR could probably be due to its location, which is more in low land compared to adjacent households to IFR. Floods as well as dry spells are among the indicators for vulnerability that were more prominent as the determinants of the livelihoods of the people because of dependence on rain-fed agriculture. During vulnerability assessment in all study cases, the score indices of exposure as well as sensitivity were relatively high than the adaptive capacity. This implied that households in the study area were vulnerable to the adverse effects of climate change calling for effective adaptation strategies.

Vulnerability indicators are useful for tracking changes in underlying processes, for measuring risk exposures and the effectiveness of adaptation strategies over time (Flanagan *et al.,* 2011). Indicators of vulnerability also help to allocate the resources to priority sectors or places (Sullivan and Byambaa, 2013). In this study, access and allocation of priority NTFPs could be given high priority to vulnerable social groups including children, old aged people, disabled people and widows to enhance their adaptive capacity. In most cases, old aged and disable people are much vulnerable to climate change adverse effects as are always physically unfit to long distances movements.

The adaptive capacity in the study area was ranked medium to both households adjacent and distant to IFR (Table 10) implying that the households in Kilombero District have relatively medium capacity to absorb the shocks and stresses from climate change. As adaptive capacity is a function of socio-economic factors, technology and infrastructure (Flanagan *et al.,* 2011), households in the study area seem to be limited to the mentioned factors because of poor financial capacity to afford them. Therefore, it is important to enhance the adaptive capacity at household level through developing (including adding value to the products) the available NTFPs from village woodlands. A study by O'Brien *et al.* (2009) revealed that vulnerability reduction can be through interventions that positively influence the context in which stressors occur either by reducing exposure or by increasing the capacity to respond. This argument is in line with observations in the current study as households were eager to receive various interventions that could enhance their adaptive capacity against current and future climate change adverse effects.

4.3 Availability and use of priority NTFPs in the study area

4.3.1 Priority NTFPs resources and availability

Twelve NTFPs were recorded during FGDs in all study villages to be used out of which three were of priority. The priority NTFPs were firewood, medicinal plants and thatch grasses mostly collected illegally from IFR, wooded grasslands and on farms. While weaving materials were of high priority in households distant to IFR, the products did not feature out in household adjacent to IFR. Such situation clearly indicated differences in the coping strategies for villages that are adjacent and distant to the forest. In the context of this study, priority NTFPs adopted for further study were those with high scores from both households adjacent and distant to IFR, because of their immediate importance in supporting households to manage adverse effects of changing climatic conditions. The priority NTFPs were used as safety net to carter mainly for household energy, health care security, roofing materials as well as income generation in the face of experienced climate stresses. The priority NTFPs are similar to those reported by other scholars in Tanzania (Augustino *et al.,* 2012; Njana *et al.,* 2013; Msalilwa *et al.,* 2013), and elsewhere in Africa (Nkem *et al.,* 2007; Kakota *et al.,* 2011).

Firewood

The majority of the respondents adjacent (61%) and few (29%) distant to IFR declared that firewood was available (Table 11) which were collected illegally from IFR, village forests and little on farms. Majority of the respondents (60%) from households distant to IFR declared that firewood was moderately available. This could probably due to limited land with trees that produce firewood unlike to households adjacent to IFR. This phenomenon could probably contribute to low adaptive capacity to adverse effects of climate change by households distant to the forest.

Table 11: **Response on availability of priority NTFPs by households in Kilombero District, Tanzania**

Priority NTFPs	*Availability levels (%)							
	HHs adjacent to IFR (n = 157)				HHs distant to IFR (n = 58)			
	1	**2**	**3**	**4**	**1**	**2**	**3**	**4**
Firewood	13	61	20	4	5	29	60	7
Medicinal plants	30	52	12	4	3	50	38	12
Thatch grasses	10	43	38	8	81	14	8	4

*Availability levels: 1 = Highly available, 2 = Available, 3 = Moderately available, 4 = Not available
HHs = Households

Firewood were collected by the majority of respondents in the study area for cooking, local beer brewing, brick burning, fish and meat smoking as well as heating and lighting. Women (Plate 3) were the most collectors of firewood mainly for cooking and heating. During FGDs, participants mentioned the most common tree species collected for firewood to include: *Brachystegia spiciformis* Benth., *B. microphylla* Harms., *Combretum* *molle* (R.Br. ex G. Don), *C. binderianum* (Kotschy) Okafa and *Diplorhynchus condylocarpon* (Müll.Arg.) Pichon. The findings from this study correspond to that by Paulo (2007) and Njana *et al*. (2013) where similar tree species were reported to be commonly used for firewood by the majority of households in Kilwa and Tabora districts, all within the Miombo eco-region zone.

Plate 3: Women having a rest at Njage Village after a long walk from the forest for firewood collection in Kilombero District, Tanzania.

Medicinal plants

The majority of the respondents adjacent (52%) and distant to IFR (50%) in the study area declared that medicinal plants were available (Table 11).

However, from Table 11 it seems only a few people did collection since the local knowledge or practice of various medicinal plant species is often passed to few individuals from the ancestors. This observation was also reported by Njana *et al.* (2013)

studying contribution of Miombo woodlands to the livelihoods of people surrounding Urumwa Forest Reserve in Tabora. In most cases, medicinal plants in the study area were mainly harvested illegally from the IFR by traditional healers and herbalists for treating different illnesses.

During FGDs, it was observed that women were more knowledgeable of many medicinal plants compared to men particularly on species associated with diseases affecting infants and pregnant women. This indicates that, most of the women in the study area have an advantage over men in terms of benefiting from medicinal plants therefore enhancing their adaptive capacity to climate change adverse effects. It was further revealed that, *Combretum molle* (R.Br. ex G. Don), *C. binderianum* (Kotschy) Okafa*, C. zeyheri* Sond*, Ficus sur* (Forssk.), *Diplorhynchus condylocarpon* (Müll.Arg.) Pichon, *Bridelia micrantha* (Hochb) Baib, *Zanha africana* (Radlk.), *Diospyros natalensis* Exell, *Vernonia colata* (Willd.) Drake, and *Bauhinia petersian* Bolle (Plate 4), were most utilized medicinal plants by the households. Similar tree species were reported by Nahashon (2013) in Tanzania and Bruschi *et al.* (2014) in the Miombo woodlands of Mozambique.

(a) **(b)**

Plate 4: Some of the common utilised medicinal plants (a) *Vernonia colata* (Willd) Drake, and (b) *Bauhinia petersiana* Bolle in Kilombero District, Tanzania.

Thatch grasses

The majority of the respondents from households distant (81%) and only few (10%) adjacent to IFR declared to have high availability of thatch grasses (Table 11). However, a proportion of about 50% of the respondents were on side that the thatch grasses were decreasing in availability due to the small area covered by grasslands, but also high pressure of conversion of wooded grasslands into agricultural fields. It was observed that most of the available village land was covered by agricultural crops especially in Mpofu and Njage villages, depending on small open patches in the IFR. Similarly, part of the land in Miwangani Village is located in lowlands dominated with wooded grasslands, which extend to the Kilombero Valley Floodplain Ramsar Site (KVFRS).

In the face of experienced climate change, adaptive capacity might be high to households closer to the forests as compared to those located distant. However, the type of management regime of a particular forest determines the extent of adaptive capacity to a particular people in terms of access to the resources. In this study, the existing forest management regime is nature reserve, whose management objective is full protection. However, currently households collect NTFPs illegally to cater for their daily needs. Due to scarcity of the priority NTFPs in village woodlands, there is a need to have formal arrangements on sustainable collection of NTFPs from the nature reserve through non-destructive methods like collection of dead wood and fruits. It is also important to promote domestication of some medicinal plants through agroforestry; this will ensure sustainable supply of the products if well managed. Also annual crop like thatch grasses can be harvested as far as they germinate and grow up easily. Moreover, to increases availability of thatch grasses, it is important to safe guard available grassland patches within the villages from other livelihood activities.

Collection of thatch grasses was done by the majority of the respondents in the study villages. In most cases, grasses were used for thatching roofs of rural houses instead of corrugated iron sheets, which were relatively expensive. In the study area, thatch grasses were specifically used for thatching many structures including households, kitchens, latrines, and several local shops. The majority of respondents in the study area admitted to collect thatch grasses for different uses including roofing, fencing and for financial purposes.

Unlike the firewood and medicinal plants which are mostly collected illegally from the IFR, availability of thatch grasses seem to be threatened by the on-going pressure on conversion of the grasslands (in general lands) into agricultural lands. Bakengesa *et al.* (2010) in Kilombero as well reported this. The most utilized thatch grasses included *Vetiveria nigritana* (Benth) Stapf and *Hyparrhenia* spp (Plate 5). According to Masam (2009) the people around New Dabaga – Ulongambi Forest Reserve, in Kilolo District reported people to use *Scleria bulbifera* Hochst.Ex.A.Rich and *Pennisetum* spp. Rich. grasses for thatching their houses. The difference in type of grasses used could probably be due to difference in indigenous knowledge and location of the two study sites. The current high demand for thatch grasses is not only for thatching houses in rural areas but also even for modern structures such as restaurants and hotels in areas that experience relatively high temperatures especially in cities and municipalities near the coast. Therefore, there is high potential of the market for thatch grasses in future from subsistence to commercial product.

(a) (b)

Plate 5: The most utilised thatch grasses (a) *Vetiveria nigritana* (Benth) Stapf and (b) *Hyparrhenia* spp for roofing and fencing in Kilombero District, Tanzania.

4.3.2 Stem density of selected priority NTFPs in Iyondo Forest Reserve

Stem density of firewood tree species

The study investigated the stem density of preferred firewood tree species, in order to assess their physical availability for standing trees and its regenerants. Stem density indicated the degree of prevalence or rowdiness of stems in the forest (Husch *et al.,* 1982).

The number of stems ha^{-1} of tree species with dbh ≥5 cm of preferred firewood in the Iyondo Forest Reserve (IFR) was 1008.65±67.11. The value of the number of stems per hectare has been derived from 67 tree species that were mentioned to be preferred for firewood, which is about 88% of all tree species recorded in this study. The dominant tree species for firewood were; *Sorindeia madagascariensis* DC, *Diplorhynchus condylocarpon* (Müll.Arg.) Pichon, *Lettowianthus stellatus Diels., Brachystegia microphylla* Harms. and *Combretum molle* (R.Br. ex G.Don) (Fig. 5). The result on the number of stems ha^{-1} in this study is relatively high compared to some cited studies in the Miombo woodlands reported in Tanzania. For example Mohamed (2006) and Mbwambo *et al*. (2012a) studying in Handeni Hill Forest Reserve, reported 817 and 677 stems ha^{-1}, respectively.

The difference in number of stem density ha^{-1} could probably be due to dissimilarity in management regimes. Noting that, IFR is now a nature reserve, which portraits high levels of protection of the resources. From the few studies referred to, it indicates that tree stand density in the IFR is stable as it is within the range of other studies elsewhere in Tanzania. Therefore, under proper use arrangements of the forest, which is now a nature reserve, households will be able to collect firewood sustainably for various household uses, thus increasing adaptive capacity against experienced climate stresses.

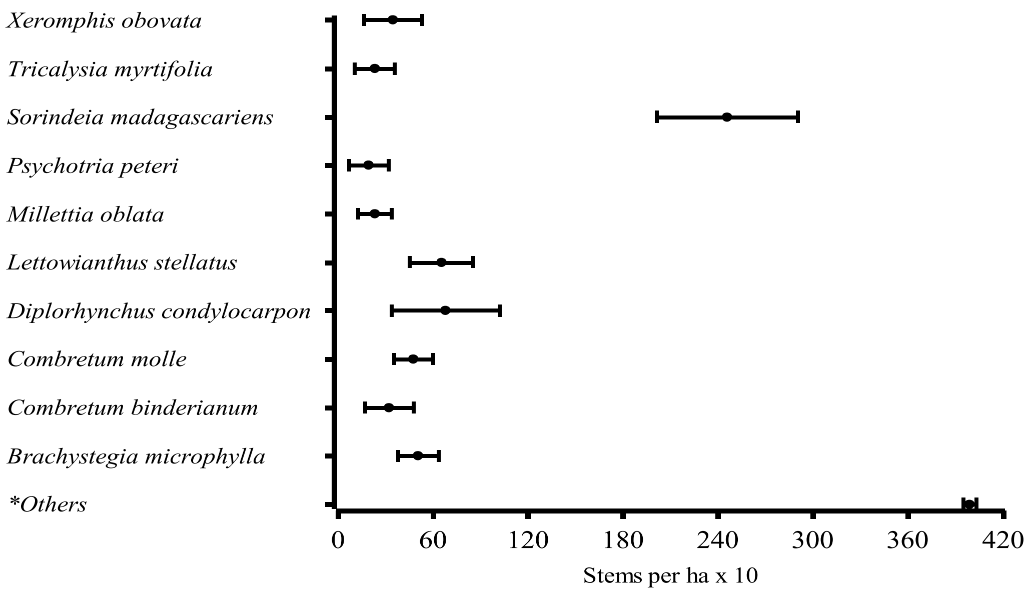


Figure 5: Number of stems ha^{-1} of dominant tree species preferred for firewood recorded from Iyondo Forest Reserve in Kilombero District, Tanzania.

*Include 58 tree species with stems ha^{-1} ranging from 0.409 to 19.22

Results on tree regenerants for firewood in this study showed that the number of seedlings ha^{-1} was 11 352.19±3311.23. Among the dominant regenerating firewood tree species were *Psychotria peteri* Petit., *Sorindeia madagascariensis* DC., *Markhamia lutea* (Benth.) K.Schum., *Lettowianthus stellatus Diels.* and *Brachystegia microphylla* Harms. (Fig. 6). The recorded number of regenerants in this study is less than the ones recorded by Mbwambo *et al.* (2012a) studying in Mgori Village Land and Handeni Hill forest reserves (both Miombo woodlands) which were 20 024 and 23 947 seedlings ha^{-1}, respectively. Less number of regenerants in this study could be attributed to little disturbances compared to Mgori Village Land and Handeni Hill and forest reserves, which are under participatory forest management, where tree harvesting is going on. Regeneration of trees was observed to be from seeds and root suckers. Prolonged dry spells and wild fires could be another factor for reduced regeneration of some tree species. This might lead to reduced adaptive capacity of households, as some of the important tree species will be less available.

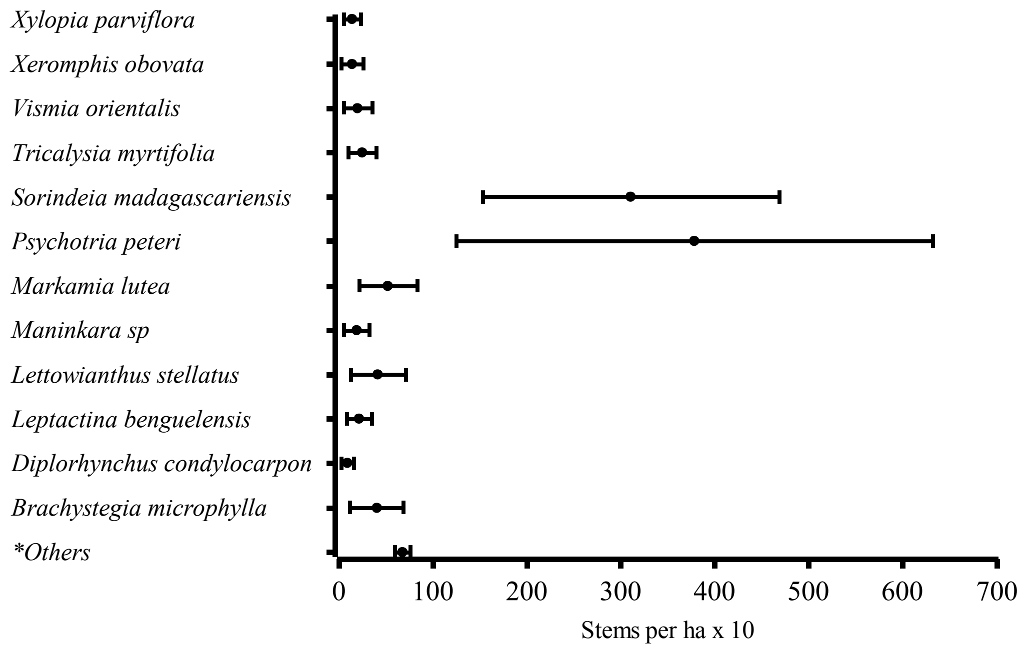


Figure 6: Number of seedlings ha^{-1} of dominant firewood tree species in Iyondo Forest Reserve in Kilombero District, Tanzania.

*Include 19 tree species with seedlings ha^{-1} ranging from 7.69 to 92.26

Stem density of medicinal tree species

The medicinal tree species with dbh ≥ 5 cm recorded in IFR had 618.66±61.81 stems ha^{-1}. The stem density is from 26 medicinal tree species, which is about 34% of all tree species recorded in this study. The dominant medicinal tree species included: *Diplorhynchus condylocarpon* (Müll.Arg.) Pichon, *Combretum molle* (R.Br. ex G. Don), *Xeromphis obovata* (Hochst.) Keay*, Combretum binderianum* and *Ficus sur* (Forssk.) (Fig. 7).

Most of the medicinal tree species recorded in this study were also observed by Augustino (2006) and Njana (2008) in the Miombo woodlands of Urumwa Forest Reserve, Tabora. Medicinal tree species are among the priority NTFPs that households claimed to use as part of their adaptation against experienced climate stresses. However, multiple use and poor harvesting techniques for some medicinal tree species might threaten sustainability of the product, and therefore reduce adaptive capacity of households. This might also cause conflicts over use of the trees species between different user groups, thus reducing adaptive capacity particularly to women and elder people.

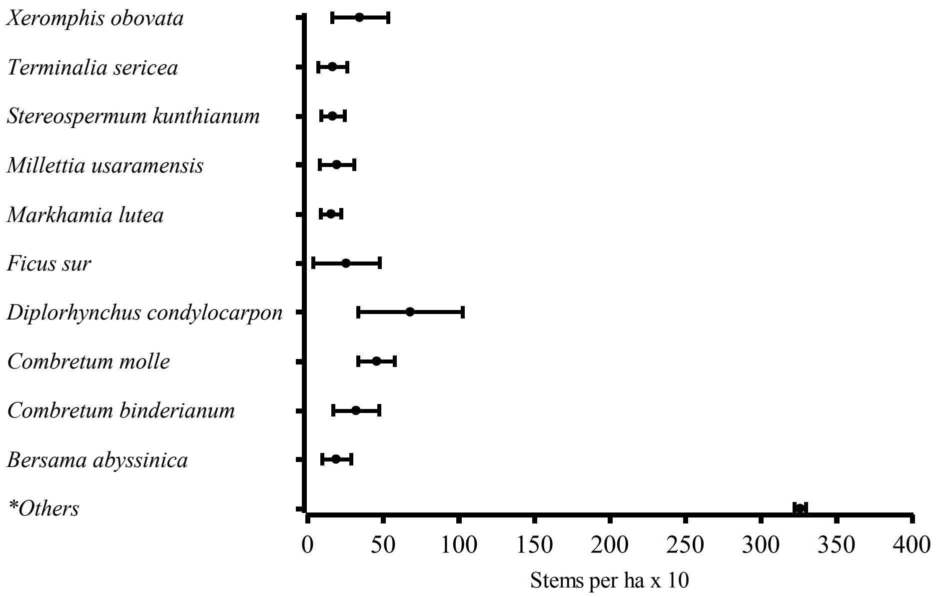


Figure 7: Number of stems ha^{-1} of tree species with medicinal value recorded from Iyondo Forest Reserve in Kilombero District, Tanzania.

*Include 16 tree species with stems per ha ranging from 0.409 to 13.87

The number of seedlings ha^{-1} for medicinal tree regenerants was observed to be 945.70±178.30 in IFR. Among the dominant regenerating medicinal tree species are *Leptactina benguelensis* (Welw. Ex Benth. and Hook.f.) R.D.Good*, Vismia orientalis, Ficus sur* (Forssk.), *Xeromphis obovata* (Hochst.) Keay and *Diplorhynchus condylocarpon* (Müll.Arg.) Pichon (Fig. 8).

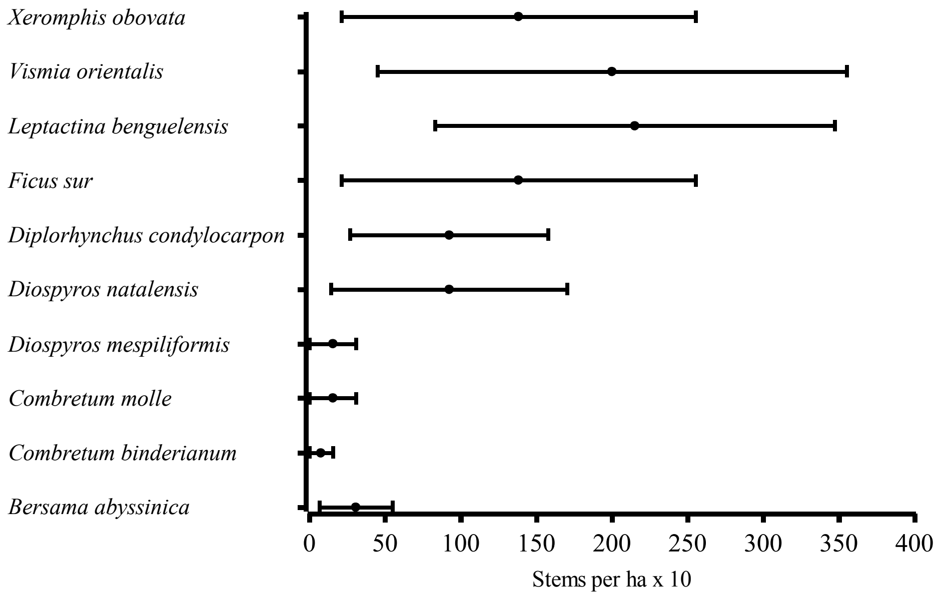


Figure 8: Number of seedlings ha^{-1} of medicinal tree species recorded from Iyondo Forest Reserve in Kilombero District, Tanzania.

The observed error in the mean is relatively high; this could probably be due to high variation between the plots. Some of the plots did not have regenerants for medicinal trees due to presence of large trees with high canopy cover which suppress undergrowth, although individuals with dbh >5 cm were observed in all study plots. An alternative plausible reason could be persistence of dry spells during rainy season and wild fires that limit germination of some seeds as well as root suckers. The implication of this observation to the context of this study is that, future availability of important medicinal tree species might be limited because of lack of succession, and therefore reducing adaptive capacity of households. Similarly, Backeus *et al*. (2006) and Chidumayo (2011) revealed a reduction in number of regenerants of some Miombo tree species because of being less tolerance to regular fires in Kilosa, Tanzania. Ex-situ conservation of such important trees species is of paramount, in order to curb the existing need.

4.3.3 Use pattern of priority NTFPs

The use pattern of priority NTFPs was in form of subsistence and trade. The majority of the respondent adjacent and distant to IFR collected priority NTFPs for subsistence and few for trade. However, annual average amount of priority traded per household was high compared to subsistence use (Table 12).

Table 12: Use pattern of priority NTFPs by households in Kilombero District, Tanzania

Use pattern	Priority NTFPs	Annual average consumption per household	
		HHs adjacent to IFR (n = 157)	HHs distant to IFR (n = 58)
Subsistence	Firewood	120.0±4.98 (72, 113)	109.60±3.93 (57, 34)
	Medicinal plants	5.8±0.39 (31, 49)	5.0±0.26 (28, 16)
	Thatch grass	29.99±1.34 (40, 63)	34.03±2.46 (81, 47)
Trade	Firewood	316.0±14.92 (26, 41)	246.40±12.96 (16, 9)
	Medicinal plants	17.85±2.99 (16, 26)	13.4±2.19 (12, 7)
	Thatch grass	38.09±1.59 (48, 75)	44.0±1.81 (68, 41)

Unit for firewood and thatch grasses is head load, equivalent to 16.55±3.33 and 14.12±3.19 Kg, respectively; while for medicinal plants is Kg.
Numbers in parenthesis are respondent frequencies (%) and counts (n) respectively;
HHs = Households

Subsistence use

Large values of priority NTFPs collected for subsistence use were recorded to both households adjacent and distant to IFR (Table 12). On average, firewood consumption per household was equivalent to 5.72±0.17 kg day^{-1}. The average unit value of the head load was estimated at TZS 2 000. The findings on household consumption of firewood per day are in line with that by Mombo *et al.* (2014) who observed a consumption rate of 5.5 kg in households in Kilombero valley wetlands. Studies by Paulo (2007) in Kilwa District and Kilonzo (2009) in people around Nyanganje Forest Reserve, Morogoro found that about 72 and 99 head loads of firewood were consumed per household per year, respectively. The difference in amount of firewood consumed could probably be due to the difference in weight of the head load, which ranged from 20 to 25 kg.

The present study has noted that firewood is an important livelihood resource especially when households become stressed by climate change effects, as among the immediate sources of household income apart from subsistence use. Income from firewood was used to carter for various households needs including education as well as health services. Previously, households depended much on income from agriculture that was used for various household needs, but currently such income is not sufficient due to reduced crop yields. This means that, most of the households did not have surplus for sale rather than only keeping for food.

The findings on annual collection of medicinal plants for subsistence use per household in the present study were lower than that reported by Paulo (2007) in Kilwa District and Kilonzo (2009) in people around Nyanganje Forest Reserve, Morogoro that were about 13 and 14 kg, respectively. The revealed difference could probably be attributed by differences in indigenous knowledge as well as type of management regime of the resources. It was further revealed that, medicinal plants are mostly used to cure wide range of ailments including water borne diseases like cholera, typhoid, dysentery and amoebic diseases. Other ailments cured include malaria, stomach ache, skin rushes, cold and cough, as well as some non-communicable diseases like diabetes and hypertension. The findings are similar to other studies done elsewhere in Tanzania (Kilonzo, 2009; Augustino *et al.,* 2012). Nkem *et al.* (2010) urged that dependency on traditional medicine is perpetuated by the fact that artificial medicinal care is limited in rural areas, and where it is available the costs are relatively high.

The results on subsistence use of thatch grasses from the current study are similar to that by Maximillian (1998) in Kibaha District, where 40 head loads of thatching grass were used per household per year. However, the current results are twice higher than those recorded by Paulo (2007) in Kilwa District, which was 16.5 head loads per household per year. The difference observed for head loads consumed per households from different localities could probably be due to type of grasses, thatching style and relative size of the houses. The houses in the study area are always re-thatched once every two years.

The current study revealed termites being among the detrimental insects as they feed on the grasses thus reducing life time while in service. It is important to apply relevant insecticides or use traditional ways that minimize conducts of thatching material and the walls. Reduced availability of grasses was also due to pressure of use by the pastoralists who set fires as part of range management with the aim of getting fresh grown grasses. This situation reduces the duration of harvesting thatch grasses. Thatch grasses are the immediate construction material when households face adverse effects of climate change such as flooding. Thatch grasses are sources of income, which is used within the livelihood capital assets, thus increasing households' adaptive capacity.

Trade of selected priority NTFPs

A significant large amount of priority NTFPs were annually traded by households adjacent and distant to IFR (Table 12). Large mean for traded priority NTFPs could probably be due to loss of income from conventional livelihood resources particularly agriculture due to climate change adverse effects. Currently households are highly depending on forests resources for income generation to carter for various human needs including health services, education and food security. However, despite large amount of priority NTFPs was traded, only few households were involved in this business compared to figures for subsistence use in all study villages.

This indicated that, although the demand for priority NTFPs in the study area was high, and only few individuals had ability to collect the resources from far apart in the forest. Also, this trend show that most of the priority NTFPs were collected for trade in order gain cash income that was used for other households' needs. Although not all of the households were aware about the changes that had occurred from the forest reserve to nature reserve, there is a need for increasing households' understanding and awareness on all matters regarding to the nature reserve. It was further reported that, trade of the NTFPs was not only done within the villages in the study area but also to nearby villages and Ifakara Town, thus increasing the scope of the business.

Trade on the priority NTFPs noted to be high during rainy season because this was the time in which households in the study area receive multiple stresses such as floods and diseases. In addition, during this time, the availability of some priority NTFPs like thatch grasses and firewood becomes low. The situation makes the demand of the products to be high and low supply. The reason behind persistence of low supply of priority NTFPs during rainy season include people being occupied more by agricultural activities as time was limited. Similarly, some of the products like thatch grasses are not yet mature; therefore trade was only to those which were stored.

4.4 Economic Value of Selected Priority NTFPs

The economic value of priority NTFPs that is firewood, thatch grasses and medicinal plants were studied. The results are presented in terms of the overall and individual economic values for priority NTFPs based on use pattern that is subsistence and trade (Table 13). Factors influencing supply of NTFPs at household level are also discussed.

Table 13: Economic value of priority NTFPs for subsistence use and trade around Iyondo Forest Reserve in Kilombero District, Tanzania

NTFP	Units	Average Quantity	Unit value	Proportion of respondents	Annual actual value (TZS)	Annual present value[a]	
						TZS	USD[b]
Subsistence							
Firewood	Head load	116.53	2 000	0.77	1 483 177 059.68	14 831 770 596.80	7 140 786.50
Thatch grass	Head load	31.33	1 000	0.63	162 681 025.00	1 626 810 250.00	783 231.15
Medicinal plants	Kg	3.53	8 000	0.47	109 566 568.64	1 095 665 686.40	527 510.50
Sub-total 1					1 755 424 653.32	17 554 246 533.20	8 451 528.14
Trade							
Firewood	Head load	292.8	2 000	0.23	1 098 554 211.84	10985 542 118.40	5 289 011.88
Thatch grass	Head load	40.06	1 000	0.54	181 186 380.51	1 811 863 805.12	872 325.56
Medicinal plants	Kg	16.39	8 000	0.15	161 985 595.55	1 619 855 955.52	779 882.99
Sub-total 2					1 441 726 187.90	14 417 261 879.04	6 941 220.42
Total (subsistence + trade)					3 197 150 841.22	31 971 508 412.24	15 392 748.57

[a]The economic values are expressed in terms of gross benefits to priority NTFP producing households
[b]Based on a mean July, 2015 exchange rate of USD 1 = TZS 2 077.05 (Bank of Tanzania, 2015)

The economic value of studied priority NTFPs for both substance and trade at a discounting rate of 10% was TZS 31.97 billion, equivalent to USD 15.39 million (Table 13). The economic value of selected priority NTFPs includes the total value of the goods that would be missing if the IFR, village forest and the grasslands were suddenly disappeared (URT, 2003). This can also be referred to as the total cost to households in the study area if the forest and wooded grasslands are completely removed or total access is denied. The economic value from the selected priority NTFPs indicated how households could increase their adaptive capacity through sustainable use of the resources for improved livelihoods.

The economic value was mainly contributed by firewood (81%) followed by thatch grasses (11%) and medicinal plants (8%). The economic value from the current study was low compared to the one obtained by Schaafsma *et al*. (2014) working around the Eastern Arc Mountains which was TZS 59 billion (USD 42 million) for firewood, charcoal, thatch grass and poles. The difference between the two studies could probably be due to the population size, method of valuation used, number of NTFPs dealt with and nature of market.

4.4.1 Firewood

In this study, the majority of respondents (77%) and few of them (23%) collected firewood for subsistence use and trade at an annual average of 116.53 and 292.8 head loads per household, respectively (Table 13). In this study, the annual present value of firewood for both subsistence and trade, at discount rate of 10% from total households of 8 308 was TZS 25.8 billion which was equivalent to USD 12.4 million (Table 11). High contribution (58%) of the annual present value was from firewood used for subsistence and the remaining proportion was for trade. This indicated that, firewood use pattern is under transition from subsistence to trade for generating income. The annual present value from this study was lower than those reported by URT (2003) and Schaafsma *et al*. (2014) which were TZS 32.6 billion (USD 32.6 million) and 36 billion (USD 25.33 million) from people around Uluguru Catchment Forest reserves, in Morogoro region and the Eastern Arc Mountains, respectively. Low value obtained from this study compared to the two past studies could be due to large number of population involved in their study as well as availability and access to the firewood. Other plausible reasons could probably be method of valuation used, and covered geographical area.

The findings further imply that firewood as part of the natural capital asset has economic value, which is significant. As the economic value for firewood was significant high, this calls for households to establish woodlots of fast growing tree species for firewood production. In future, such woodlots can be used as collateral to various financial institutions and access development funds, which will be used to carter for various households' needs therefore increasing adaptive capacity to households to adverse climate change effects as well as extreme events.

On the other hand, the present study recorded high annual present value compared to TZS 4.6 billion (USD 4.2 million) and 84.2 million (USD 64 731); that were reported by Msemwa (2007) and Kilonzo (2009) for people surrounding general lands in Kilosa and Nyanganje Forest Reserve Kilombero districts, respectively. The differences observed could probably be attributed by the average amount of head loads collected per year per household, valuation method used and scope of the study. Another plausible reason could be change in use pattern from subsistence to trade of firewood for income generation in order to carter for various household needs in the face of changing climate with adverse effects on conversional livelihoods including agriculture. According to Nkem *et al.* (2010), NTFPs are essentially the niche for poor population, which make them relevant for addressing poverty, health problems and adaptation to external shocks and stresses due to climate change effects.

4.4.2 Thatch grasses

In the study area, thatch grasses were collect by the majority of respondents both adjacent and distant to IFR for subsistence (63%) and trade (54%), with an annual average of 31 and 40 head loads per household, respectively (Table 13). The mean annual present value for thatch grasses for both subsistence use and trade for 8 308 households, at a discounting rate of 10% was estimated at TZS 3.4 billion, which was equivalent to USD 1.7 million (Table 12).

The findings from this study indicate higher value than those reported by Schaafsma *et al*. (2014) studying in the Eastern Arc Mountains which was about TZS 220 million (USD 0.16 million), probably due to differences in study population size and geographical coverage. Other plausible reasons could be due to differences in market price, valuation method, indigenous knowledge and purpose of collection of the thatch grasses in a particular location. Another plausible reason for the high value of the thatch grasses in study are could be due to scarcity of the resources especially in Mpofu Villages whereby people collected informally in open areas within the IFR and formally at the Roman Catholic Mission farm in Mbingu Village. High amount of thatch grasses collected were also related to current adverse effects of climate change in the area. Increased temperatures were related to increase in termite activity on thatch grasses in the houses.

Also during flooding, housed were demolished, making thatch grasses the immediate roofing materials. The results from the current study were however lower than TZS 7.5 billion (USD 6.8 million) reported by Msemwa (2007) in Kilosa District. The difference observed could be due to population size, valuation method, availability and the accessibility to the products. The latter study was carried out in general lands of Kilosa District, therefore depicting full access to the products unlike to the IFR and surrounding environment.

According to Schaafsma *et al*. (2012), better enforcement of conservation policies is expected to increase costs of NTFPs collection and therefore reduce extraction levels, either directly through costs of licensing, fines or bribery, or indirectly through the risk – premium on illegal collection when avoiding fines. As the study has recognized economic value of the thatch grasses, it is important for households to retain some of the open grasslands that are found within their farms for this purpose. The government could facilitate preparation of land use management plan in order to that open grassland areas are considered, therefore retaining them for thatch grass production and other related activities like fodder.

4.4.3 Medicinal plants

Medicinal plants were collected by 47% of the respondents for subsistence and 15% for trade in the study area (Table 13). An average of 3.5 and 16.4 kg of medicinal plants were annually collected per household for domestic use and trade respectively. The annual present value for medicinal plants used for subsistence and trade at a discounting rate of 10% was TZS 2.7 billion equivalent to USD 1.3 million (Table 11). The annual present value recorded in this study was lower than TZS 3.7 billion (USD 3.3 million) recorded by Msemwa (2007) in Kilosa District. The reason behind the differences could be due to population size, valuation method, free access, availability of the products and religious beliefs, since some respondents' associate use of medicinal plants with witchcraft.

On the other hand, Kilonzo (2009) studying in Nyanganje Forest Reserve in Kilombero District, reported an annual present value from medicinal plants of TZS 3.3 million (USD 2 585). The present study has recorded high values of annual present values than that by Kilonzo (2009). This could be attributed by the difference in unit value of the medicinal plants which was TZS 8 000 per kg for present study compared to TZS 500 per kg in 2009. The findings imply that medicinal plants have significant economic value that can contribute to the natural capital asset and its value is increasing daily. Therefore, households could be encouraged to retain on farms some of the tree and shrub species with medicinal values. Together with this, ex situ conservation of important medicinal trees is pertinent, whereby medicinal plants that are not available in a particular locality can be taken and planted into another area. This will increase availability and therefore serve households against diseases that currently prevail due to adverse effects of climate change effects.

4.4.4 Factors influencing collection of NTFPs at household level

Collection of NTFPs was influenced by distance to the forest, change in forest management regime, seasonality and change in rainfall pattern (Table 14). Majority of the respondents adjacent (62%) and few (47%) distant to IFR reported that increasing distance to the forest and wooded grasslands which hinders rate of collection of NTFPs (Table 14). The amount of NTFPs collected decrease as distance increases. This means that opportunity cost of labour time spent for collections increase with distance, also indicates that people living closer to the forest are more dependent on NTFPs despite the restrictions imposed. On the same vein, as distance continue to increase, some of the social groups such as old people, disabled, widows and children could not be able to access the priority NTFPs, so could be negatively affected by the climate change as their adaptive capacity is limited.

Table 14: Factors influencing collection of NTFPs at household level in Kilombero District, Tanzania

Factors	Response (%)		χ^2	P value
	HHs adjacent to IFR (n= 157)	HHs distant to IFR (n = 58)		
Distance to the forest	62	47	9.831	0.033*
Change in forest management regime	48	Nr	17.354	0.042*
Seasonality	39	46	2.060	0.657Ns
Change in rainfall pattern	42	51	3.293	0.964Ns

The response (%) is a result from multiple responses analysis; Nr = No response; HHs = Households; Ns = Non significant; *= Significant at $P \leq 0.05$; χ^2 = Chi-Square value

Distance

The IPCC Firth Assessment Report (Olsson *et al.,* 2014) argued that the socially and economically disadvantaged and marginalized people are disproportionately affected by the impacts of climate change and extreme events. Similarly, for people surrounding Nyanganje Forest Reserve, collection of firewood was significantly decreasing with increasing distance (Kilonzo, 2009). This implied that households residing near IFR still depend more on NTFPs such as firewood and mushroom than those located distant; and this might contribute to increasing their adaptive capacity to adverse climate change and vice versa.

Change in forest management regime

Since 2007, the then IFR changed management regime to nature reserve. A nature reserve is the highest category of protected areas, which do not allow human consumptive activities (Harrison, 2006). About 48% of the respondents adjacent to IFR (Table 14) claimed that restricting access to the forest has decreased the supply of NTFPs at their households, hence increasing their vulnerability to adverse effects of climate change. There was no response to households distant to IFR, probably because the tenure of the wooded grasslands is still under village government management.

Results further indicate that upgrading management status from forest reserve to nature reserve was another stress to households. However, discussing with the forest officer in charge, it was revealed that currently there is informal arrangement that allow households to enter into the forests to collect some few non-destructive NTFPs like dried firewood, mushrooms, fruits and wild vegetables. This type of informal arrangement could not be sustainable as it depended on the willingness of the conservator in charge at that time. One of the key informants at Mpofu Village reported that:

"………Currently we are informally allowed to collect some products in the Iyondo Forest Reserve like dry firewood, mushrooms, fruits, and wild vegetable. However, due the changes in rules and regulations they have made to our forest we might not be able to access the forest in future; the government should consider our livelihoods"

It was further noted that law enforcement was mainly on harvesting timber, poles and hunting of wild games in the nature reserve. However, not all of the households were well informed about the current prevailing legal structures. Therefore, restriction on forest access to promote conservation requires additional policies to prevent a consequent increase in poverty, and an enforced trade – off between conservation and extraction of NTFPs (Schaafsma *et al.,* 2011). It could be appropriate if surrounding population could be allowed to use the nature reserve for activities, which do not pose a threat, but enhances conservation such as beekeeping. Other activities, which can be conducted in a reserved forest if carefully planned according to Chidumayo (2011), include collection of firewood from dead logs, wild fruits, honey and medicinal plants.

The findings in this study are in line with those by Mombo *et al.* (2011) which indicated that, about 87% of the local people were not aware whether there is a specific law, which prohibits them from performing specific activities in the Kilombero Valley Floodplain Ramsar Site (KVFRS). The authors further showed that, some of the local people did not know whether the wetland was designated as Ramsar Site, their understanding was that it belongs to Seleou Game Reserve. This situation is similar to IFR, which is now under the Kilombero Nature Reserve, as majority of the households (73%) were confidently aware that it is under the Tanzania National Park Authority (TANAPA), because law enforcement has been as high as those practiced in the parks. As the rules and regulation governing the nature reserve might become stricter than now, it is therefore important for priority NTFPs to be cultivated outside the forests.

Seasonality

Seasonality was one of the constraints, which hindered collection of NTFPs by both households adjacent (39%) and distant (46) to IFR (Table 14). It was reported that, some products such as mushrooms are only available from February to April. Wild fruits such as Tamarind are collected from July to November. Other NTFPs, which are available only in some months of the year, include wild vegetables and thatch grasses. Data from FGDs show that availability of different NTFPs is declining due to changing climatic conditions, which has resulted into shift of seasons.

Similarly, seasonality of wild fruits (Marula) in South Africa, which is only available in summer have been reported to affect production of Amarula beer (Makhado *et al.,* 2009). When mushrooms and wild vegetables are available some household use them almost daily. Peak season of Tamarind fruits occur during the dry season when other fruits for making beverages are not available. Households reported to dry and store mushrooms and wild fruits for some period of time but the processing and storage conditions were noted to be poor. Therefore, mushrooms, wild vegetables and wild fruits availability can be improved if adoption of simple but improved technologies of processing and storage will be promoted to households for anticipatory adaptation.

Change in rainfall pattern

Table 14 indicates that both respondents adjacent (39%) and distant to IFR revealed change in rainfall pattern to negatively affect supply of some NTFPs. Change of rainfall pattern and intensity has led to lower supply of some NTFPs like mushroom and wild vegetables. Normally in December, varieties of mushrooms collected are *Amanita zambiana* (wilelema) and *Termitomyces letestui* (wikulwe), but due to changing of onset and cessation of rainfall in recent years, they are less available. The empirical data show that rainfall in the study area has been unpredictable. The rainfall pattern from 1980 to 2010 showed a trend of decrease in total rainfall received for the past three decades (Fig. 3 and 4). This implied that the study area has been receiving high rains for short period, as was perceived by the majority. Also, from the indigenous knowledge perspective of some respondents, it was reported that prolonged drought have increased the chance of occurrence of wildfire which burn all litters in the forest that form substrate for mushrooms to grow, hence decreasing the supply of mushrooms.

Similarly, Chidumayo *et al*. (2011) reported effect of climate change on availability of forest product and services through forest fires, which are associated to drought, resulting into biodiversity loss. As most of the NTFPs including thatch grasses and litters for mushroom growth are affected by wildfires, it is important for forest managers to have different mechanisms for fire control including sitting together with households for discussion on how they can manage fires that originate from their farms. Education on fire control and management could also continue to be given to households as far as the occurrence of dry spells might persist.

4.5 Current Role of Priority NTFPs Resources and other Strategies in Managing Changing Climatic Conditions

The study has explored roles of priority NTFPs in managing changing climatic conditions including climate change specifically focusing on the contribution of selected priority NTFPs to livelihood capital assets; how households use selected priority NTFPs in addressing climate stresses in the study area; as well as contribution of selected priority NTFPs to the household annual income. Other developed adaptation strategies apart from priority NTFPs were as well studied.

4.5.1 Role of priority NTFPs resources

The role of NTFPs resources as coping strategy against climate stresses has been revealed in the current study. Selected priority NTFPs that included firewood, medicinal plants and thatch grasses are part of the natural capital assets, which contribute to the livelihood of the households. The selected priority NTFPs contributed substantial amount to other capital assets like financial, human and physical therefore realizing livelihood outcomes through improved household energy, health care as well as construction material.

NTFPs a strategy for managing changing climatic condition

Table 15 shows NTFPs were among the coping strategies for climate change adverse effects. Households adjacent and distant to IFR claimed to respond to adverse effects of climate change especially floods by increase their reliance to casual labouring, use of NTFPs than it used to be over the past decades and petty trade (Table 15).

Table 15: Developed strategies for managing changing climatic conditions in Kilombero District, Tanzania

Coping strategies	Response (%)		χ^2	P value
	HHs adjacent to IFR (n= 157)	HHs distant to IFR (n = 58)		
Casual labour	18.2	27.6	9.736	0.021*
Use of NTFPs	21.0	14.3	9.369	0.604Ns
Selling livestock	2.6	10.0	6.632	0.036*
Remittance	2.2	1.8	5.064	0.167Ns
Petty trade	4.6	7.3	2.726	0.436Ns
Selling rice and buying maize	2.1	2.5	6.112	0.106Ns

The response (%) is a result from multiple responses analysis; HHs = Households; Ns = Non significant; *= Significant at $P \leq 0.05$; χ^2 = Chi-Square value

From Table 15, some of the households adjacent (18%) and distant (28%) to IFR were involved in casual labour activities for income generation in order to cope with the frequent floods and dry spells that occurred in the study area. The use of NTFPs was also mentioned by a small proportion of respondents adjacent (21%) and distant (14%) to IFR to cater for food, construction and generate income that was used for various domestic needs during times of hardship. However, majority of the respondents admitted to collect NTFPs unknowingly responding to climate change adverse effects.

The commonly mentioned NTFPs included mushrooms, firewood, medicinal plants and edible fruits were collected from the Iyondo Forest Reserve (illegally), in village woodlands and on farms. During FGDs, people mentioned that, village woodlands and on farms were the most reliable alternative sources of NTFPs that could provide the products if sustainably managed. Results imply that NTFPs could probably form part of the coping and adaptation strategies for households resources if well developed to ensure sustainability.

Nkem *et al.* (2010) have reported similar findings in the Democratic Republic of Congo (DRC) where people have gone into commercialization of some NTFPs such as medicinal plants, mushroom, caterpillars, fish, bush meat and palm wine for climate change adaptation. This could apply to the people in Kilombero District if domestication and value addition could be emphasized for the existing potential NTFPs in order to enhance households' adaptive capacity and in turn help to improve income and food security at household level. During FGDs, households reported existence of organizations including the KNR and Eastern Arc Mountains Conservation Endowment Fund (EAMCEF) that were involved in provision of environmental conservation education to households. These institutions seem to support households in their efforts to cope with the adverse effects of climate change.

The KNR through the Village Environmental Committees (VEC) was reported to be involved in creating awareness on tree planting around homesteads and on farms, in situ conservation of some important NTFPs tree species, and beekeeping. Similarly, the EAMCEF has been supporting households by enabling them to establish some small developmental projects including tree planting, fish farming and beekeeping.

The organisation provided funds as well as education on various development projects. All these activities aimed at diversifying livelihoods strategies out of crop farming. All these efforts are towards adaptation through use of NTFPs. As proposed in the IPCC Firth Assessment Report (Smith *et al.*, 2014b) NTFPs are important for the climate resilience of local livelihood systems because natural forests are more resilient to climate change effects than monoculture plantations.

The results further revealed that, use of NTFPs as a strategy for managing adverse effects of changing climatic conditions was gender sensitive with both involvements of men (54%) and women (46%) for households adjacent to IFR such as mushrooms especially when agricultural crops were negatively affected (Table 16). In two decades ago, activities like mushroom and firewood collection were reported to be done by women only. No response was revealed from households distant to the IFR, implying that such households have limited number of coping strategies to the adverse effects of climate change. Products like *Hyphaene compressa* H. Wendel. (*malala*) and *Phoenix reclinata* Jacq. (*ukindu*) were collected by both men and women by households distant to the IFR. These products were readily available in grassland areas, therefore forming part of coping strategies to household distant to the forest.

Table 16: NTFPs as adaptation to climate change effects in Kilombero District, Tanzania

NTFPs	**Responses (%)**			
	HHs adjacent to IFR		**HHs distant to IFR**	
	M	F	M	F
Wild mushrooms	54	46	Nr	Nr
Construction materials (thatch grass, withies, ropes)	14	22	7	5
Firewood	14	17	Nr	13
Edible fruits	3	3	Nr	Nr
Edible tubers	14	10	Nr	Nr
Medicinal plants	3	3	Nr	5
Hyphaene compressa H. Wendel. (*malala*)	Nr	Nr	53	27
Phoenix reclinata Jacq. (*ukindu*)	Nr	3	13	23

The response (%) is a result from multiple responses analysis; HHs = Households; Nr = No response; M = Male; F = Female

The difference in gender roles within NTFPs as adaptive measure among user groups could probably be attributed by socio-economic factors within the gender roles. For example collection of firewood, wild vegetable and mushrooms in the past (two decades ago and beyond) was mainly done by females (Msuya *et al.,* 2010). Currently in the study area, involvement of men in collection of some NTFPs like firewood and mushroom is high because of financial income obtained from them, as in the past they depended much on income from agriculture, which is not doing well nowadays because of adverse effects of changing climatic conditions. Augustino *et al.* (2012) and Msalilwa *et al.* (2013) in selected parts of Tanzania, whereby both men and women did collection of NTFPs, have reported similar results. This indicated that households rely much on NTFPs to generate cash income. The findings in this study are also similar to those recorded by Nindi and Mhando (2012) in Mbinga District, where both men and women collected mushrooms, medicinal plants and construction materials as their immediate coping strategies to climate change effects.

On the other hand, use of weaving materials which were locally known as *malala* (*Hyphaene compressa* (H.) Wendel.) plant to make various products was revealed to be a strategic activity by more men (53%) compared to women (27%) in the study area (Table 16). This was because women preferred more another type of weaving material known as *ukindu* (*Phoenix reclinata* Jacq.) due to its high value for the final product compared to *malala*. The use of NTFPs as an adaptation strategy is well emphasized in NAPA especially during periods of extreme weather conditions (URT, 2007). It is suggested that, efforts be made to conserve some patches of woodlands where these NTFPs grow in order to ensure sustainable supply of the products.

Contribution of selected priority NTFPs to livelihood capital assets

The selected priority NTFPs (firewood, medicinal plants and thatch grasses) are part of the natural capital asset that contribute to the livelihood of the households. Livelihoods depend on access to capital assets in which people draw upon to combine, transform and expand their assets; and the ways people deploy and enhance their capabilities to act and make lives meaningful (Scoones, 1998). In this study, firewood contributed to two livelihood capital assets namely financial and human (Table 17).

Table 17: Households' response on the contribution of priority NTFPs to livelihood capital assets in Kilombero District, Tanzania

Variable	Response (%)		χ^2	P value
	HHs adjacent to IFR (n = 157)	HHs distant to IFR (n = 58)		
Firewood				
Financial capital	7	10	1.578	0.45Ns
Human capital	18	29	9.672	0.021*
Human and financial capitals	75	61	0.394	0.945Ns
Medicinal plants				
Financial capital	18	7	9.372	0.015*
Human capital	40	65	11.372	0.012*
Human and financial capitals	41	31	0.232	0.765Ns
Thatch grasses				
Financial capital	32	17	10.365	0.015*
Physical capital	29	9	8.472	0.045*
Physical and financial capitals	38	78	6.372	0.021*

HHs = Households; Ns = Non significant; *= Significant at $P \leq 0.05$; χ^2 = Chi-Square value

Contribution of firewood to financial capital assets occurred when households generate income from it. While subsistence use of the firewood at household level was related to human capital asset. The majority of the respondents adjacent (75%) and distant to IFR (61%) indicated that firewood contributed to both human and financial livelihood capital assets at household level (Table 17). The findings showed the extent to which households collected firewood for subsistence use and trade. The most common firewood tree species collected for subsistence use and trade were; *Brachystegia spiciformis* Benth., *B. microphylla* Harms., *Combretum molle* (R.Br. ex G. Don)., *C. binderianum* and *Diplorhynchus condylocarpon* (Müll.Arg.) Pichon. Most of the firewood collected in Miwangani Village that is distant to IFR was reserved for subsistence use and is a scarce resource, because there is no surplus for sales.

During FGDs, households reported that 'contribution of firewood in human capital asset was in terms of warming, heating, cooking food staff and lighting'. Lighting at night using firewood was reported by the majority households in Miwangani Villages especially in small houses located at farming areas, as people did not have alternative lighting sources such as kerosene lamps, solar lamps, and dry cell torches, to mention few. As firewood has been very important in the study area at household level, there is a need to promote tree planting for wood energy production. Taking note that, indigenous tree species in the forests and woodlands are dwindling, therefore the village government or individuals could set aside areas for establishment of wood energy woodlots. Taking note that, coping to adverse climate change effects through use of NTFPs could be high to households adjacent to forests compared to those distant because limited products.

On the other hand, medicinal plants contributed mainly in human capital asset as was reported by the majority of the respondents (65%) from households distant to IFR (Table 17). While a proportional of 40% collected medicinal plants for the same purpose from households adjacent to IFR. Small proportion of respondents from households adjacent to IFR could be due to limited access to IFR to collect the products. Furthermore, the findings showed that, the majority of the respondents collected medicinal plants for subsistence use. Few of them, about 41% and 31% of respondents from households adjacent and distant to the IFR respectively, collected medicinal plants specifically for sale, which contributed to financial capital asset. High reliance on medicinal plants indicated that most of the households were not able to afford modern treatments because of either limited health centres or cash income. Most of the popular remedies were reported to be common to the majority of the households. To mention few, a decoction of roots of *Terminalia sericea* Burch. ex DC. was claimed to treat diarrhoea, vomiting and stomach-aches, gonorrhoea and bilharzia. While, a decoction of roots and leaves of *Combretum collinum* Fresen. was claimed to cure malaria as well as excessive menstrual bleeding beyond the normal time. Powdered roots of *Combretum molle* (R.Br. ex G. Don) were claimed to treat worms, fever and dysentery. Hot-water extract of root and stem bark of *Combretum zeyheri* Sond. was claimed to treat diarrhoea, dysentery and vomiting.

Fresh leaves (boiled in water) of *Ficus sycomorus* L. were claimed as a remedy against tuberculosis, commonly known as TB (*Tubercle bacillus*) and cough; Bark (powder) of *Zanha africana* (Radlk.) Exell were claimed to treat asthma and cough. Dependence on medicinal plants as a primary healthcare by rural people around forests has also been reported elsewhere by other scholars in Tanzania (Kitula, 2007; Otieno *et al.,* 2011; Kayombo *et al.,* 2013; Njana *et al*., 2013; Nahashon, 2013; Augustino *et al.,* 2011, 2014). From this study, it is suggested that, households have to retain on their farms some of the important medicinal trees and shrubs that are currently available. In addition, for tree and shrub species that are not found on their farms, efforts to recruit such important trees species from the forest could be given priority. Awareness could be given to households on how to raise some of the tree and shrub species of great importance. Increasing availability of the medicinal resources around their homestead will increase supply and therefore increase adaptive capacity of the people to adverse effects of climate change stresses and shocks.

Thatch grasses also played a role in contribution to livelihood capital asset, particularly to physical and financial capitals. Common thatch grasses that were most preferred for roofing were *Vetiveria nigritana* (Benth) Stapf and *Hyparrhenia* spp. It was observed that, the majority (78%) of the households distant to IFR, and only few (38%) of the households adjacent to IFR, collected thatch grasses for both subsistence and cash, and there was significant difference ($P \leq 0.05$) between the two strata (Table 17). The findings imply that collection of thatch grasses is one of the major coping strategies by households distant to the IFR, that is important for enhancing their adaptive capacity to adverse effects of climate change.

The results further imply that, the majority of the respondents in study area were involved much in collection of thatch grasses for both subsistence and cash particularly in Miwangani Village. This could probably be due to limited alternative sources of income apart from agriculture. Noting that, agriculture was the main source of income, but currently yields have been reduced, therefore increasing dependence on NTFPs for income generation. Another plausible explanation for this phenomenon is that, part of the land in the study area was covered by wooded grassland vegetation. However, through FGD in the village, it was reported that most of the thatch grasses were obtained from the open grasslands and illegally from the KVFRS. This implied decrease in adaptive capacity of the households that are limited with other forest products. It is therefore important for households to retain open areas within the grasslands for production of thatch grasses.

Table 18 gives detailed information on how households utilized priority NTFPs in addressing climate change stresses perceived in the study area, which include prolonged dry spells, floods, heavy rains and extreme heat. The households used the priority NTFPs as a way of increasing adaptive capacity to climate change stresses. Some of the reported consequences of the effects of climate change stresses include outbreak of pests and diseases affecting human beings, crops and livestock, reduced water flow in streams and rivers, crop and houses damage and loss, and household food insecurity.

Table 18: **Households use of priority NTFPs in addressing climate stresses in Kilombero District, Tanzania**

Climate stresses	Adverse effects	Role of priority NTFPs
Prolonged dry spells	• Drying up of crops • Outbreak of pests and diseases that affect human, crops and livestock • Reduced water flow in streams and rivers • Reduced water quality • Household food insecurity • Wild fires	• Income obtained from priority NTFPs is used for various services including food security, education, healthcare, and construction materials • Medicinal plants are used as remedy to diseases affecting human beings and livestock • Thatch grasses are used to re-thatch damaged houses after severe storms and floods.
Heavy rains and floods	• Crop damage and loss • Damage to human dwellings • Disrupt roads • Reduced water quality • Outbreak of diseases like cholera • Income loss • Household food insecurity • Loss of livestock	• Income obtained from priority NTFPs is used to carter for various services including food security, education, healthcare, and construction materials • Firewood used as immediate source of household energy • Medicinal plants are used as remedy to diseases affecting human beings and livestock • Thatch grasses are used to re-thatch the damaged houses
Extreme heat	• Outbreak of pests and diseases affecting human beings, crops and livestock • Crop damage and loss • Reduced manpower and livestock • Reduced water flow in streams and rivers • Wild fires • Loss of livestock	• Medicinal plants are used as remedy to diseases affecting human beings and livestock • Income from NTFPs is used to buy food, pay for artificial pesticides as well as pest and disease resistant seeds • Thatch grasses are used for roofing (reduces heat from sun during high temperature seasons) • Some of the thatch grasses are used as fodder for livestock

Contribution of selected priority NTFPs to the household annual income

Findings from this study showed that priority NTFPs contributed about 3% of the total household annual income (Table 19). Large amount (71%) of the income from NTFPs was obtained from households adjacent to IFR. This indicated that households adjacent to the IFR, collected large amount of the products though illegally. This further implies that, there is high dependence to the forest reserve by these households despite changes in rules and regulation governing the access. In the context of this study, the income from the priority NTFPs were from firewood, medicinal plants and thatch grasses. The priority NTFPs fetched forth position after livestock, petty business and agricultural crops. Agriculture was the main source of income contributing to 73% of the total household annual income (Table 19).

Table 19: **Main income sources of respondents in Kilombero District, Tanzania**

Income source	Mean annual household income (TZS)		Total (TZS)	% share
	HHs adjacent to IFR (n= 157)	HHs distant to IFR (n = 58)		
Agricultural crops	3 874 366.67	1 154 116.67	5 028 483.33	73
Petty trade	430 933.33	146 450.00	577 383.33	8
Livestock	222 150.00	92 150.00	314 300.00	5
*NTFPs	167 375.00	68 766.67	236 141.67	3
Formal employment	93 333.34	53 933.33	147 266.67	2
Casual labour	88 850.00	47 316.67	136 166.67	2
Remittance	107 083.34	19 150.00	126 233.33	2
**Others	270 676.67	66 333.33	337 010.00	5
Total	5 254 768.33	1 648 216.67	6 902 985.00	100

*Income from firewood, medicinal plants and thatch grasses
**Include activities like motorbike '*bodaboda*' transport, carpentry, masonry, fishing, weaving, brick making and local brewing.

Contribution of the priority NTFPs to the annual household income in the present study is relatively higher than that recorded by Msemwa (2007) studying in Kilosa District, which was 0.9% of the total household annual income. The annual household income value from selected priority NTFPs in this study were also higher than that reported by Kilonzo (2009) studying around Nyanganje Forest Reserve, in Kilombero which was TAS 161

967. The high contribution of the NTFPs to household income was reported by Hamza *et al.* (2007) studying around Mgori Forest Reserve in Singida District and Paulo (2007) in Kilwa, which accounted for 35% and 38%, respectively of the annual household income The plausible reasons for the difference could be attributed by socio-economic setting of the area, indigenous knowledge as well as utilization preferences of the products that may have effect on increasing or reducing pressure on the resources. Other reasons that could have attributed to these differences might be due to the variation in economic returns from the productive activities and can even be because of the richness of natural resource stocks.

In this study, households relied much on the priority NTFPs to carter for household energy, health care security, shelter (roofing materials) because of frequently experienced climate change adverse effects such as prevalence of pest and diseases, dry spells, floods and termites that were claimed to destroy thatching grasses in service. Utilization pressure on selected priority NTFPs was also claimed to be influenced by the prevailing adverse effect of climate stresses on agricultural crops, which are the main livelihood to most of the rural population (Eriksen *et al.,* 2005; URT, 2012a).

4.5.2 Other developed local adaptation strategies

Following the realized adverse effects of climate change, households have acted in numerous ways and diversified their strategies apart from NTFPs. The responses have been either farming and or non-farming. Farming strategies include crop diversification, changing cropping calendar and adopting modern farming techniques (Table 20). Few of the respondents (Table 20) did not have adaptation strategies; however, during FGDs it was revealed that, some of them practiced adaptation strategies unknowingly.

Table 20: Other climate change adaptation strategies practiced in Kilombero District, Tanzania

Strategies	Response (%)		χ^2	P value
	HHs adjacent to IFR (n= 157)	**HHs distant to IFR (n = 58)**		
Crop diversification	86	83	0.539	0.941Ns
Changing cropping calendar	80	81	0.632	0.681Ns
Adopting modern faming technologies	70	48	8.856	0.025*
No adoption	7	11	1.284	0.735

The response (%) is a result from multiple responses analysis; HHs = Households; Ns = Non significant; *= Significant at P≤0.05; χ^2 = Chi-Square value

Both households adjacent and distant to IFR practiced crop diversification which involved growing different varieties of food and cash crops, some of which are resistant to dry spells and some pests and diseases. Crop diversification aimed to supplement traditional crops with non-traditional. Traditional crops were rice (*Oryza sativa* (L.)), banana (*Musa* spp.) and maize (*Zea mays* (L.)) (Table 21).

Table 21: Main crops (traditional and non-traditional) grown in Kilombero District, Tanzania

Crops grown		Response (%)	
Botanical names	**Common names**	**HHs adjacent to IFR (n= 157)**	**HHs distant to IFR (n = 58)**
Traditional crops			
Paddy (*Oryza sativa* L.)	Paddy	83	100
Maize (*Zea mays* L.)	Maize	89	90
Banana (*Musa* spp.)	Banana	52	53
Coconut (*Cocos nucifera* L.)	Coconut	2	Nr
Non-traditional crops			
Sesame (*Sesamum indicum* L.)	Sesame	28	3
Cassava (*Manihot esculenta* Crantz)	Cassava	27	12
Sweet potatoes (*Ipomoea batatas* L.)	Sweet potatoes	14	22
Cocoa (*Theobroma cacao* L.)	Cocoa	4	Nr
Groundnuts (*Arachis hypogaea* L.)	Groundnuts	3	2
Pigeon peas (*Cajanus cajan* L.)	Pigeon peas	9	19
Cow peas (*Vigna unguiculata* L. Walp)	Cow peas	Nr	13
Sugarcane *Saccharum* spp.	Sunflower	2	10
Sunflower *Helianthus annuus* L.)		4	Nr

The response (%) is a result from multiple responses analysis

The study also observed households growing fast growing food crop varieties including Stuka and Staha for maize and SARO 5, TXD 88 and TXD 85 for rice. Cash crops like sesame, cocoa and sunflower constituted recently introduced crops to diversify agricultural activities. In Mpofu for example, sesame has been grown since 2000, while in Njage and Miwangani started in 2007. Sunflower crop is becoming famous in recent years in the study area because it tolerates moisture stresses. Similar studies elsewhere (Ellis, 2000; URT, 2007; Paavola, 2008; Sanga *et al.,* 2013) have indicated how crop diversification is important as a way of adapting to the adverse effects of climate change.

The majority of the respondents in the study area (Table 18) also observed change in crop growing calendar. The both households adjacent and distant to the IFR were shifting crop growing calendar through early cultivation since rains were neither reliable nor predictable. Early planting was claimed to be a viable climate change adaptation mechanism as it allowed optimization of unpredictable, unreliable rainfall by ensuring crops were already established on the farm when the rains commence. Focus group discussion noted that in the past decades (1990s and beyond) households received first short rains in October to November and persisted until January. Currently, people are using the first rains in November for crop planting, compared to the past where it was time for weeds to germinate. It is important for the TMA to verify change in onset and cessation of rainfall and temperature in order to have empirical evidence on this argument.

With regard to adoption of modern farming, significant difference ($P \leq 0.05$) was observed between household adjacent and distant to IFR (Table 18). The study revealed availability of irrigation canal that was constructed in 2006 in Njage village, which is used for rice production (Plate 6a).

The irrigation scheme abstracts water from Njage River in the Iyondo Forest Reserve by gravity-fed canals. The irrigation scheme was constructed in order to supplement water in some agricultural fields that were cultivated during dry season. In the 1990s and beyond, such fields used natural spring water and some intermittent rains that currently are not available. Currently there is renovation and extension of the irrigation scheme at Njage (Plate 6b). Similar findings were recorded by Sanga *et al.* (2013) in Pangani River Basin and Pemba in Tanzania where farmers use irrigation system to adapt with the adverse effects of climate change. Both households adjacent and distant to IFR have adopted use of pesticides, herbicides and row planting instead of broadcasting seeds.

(a) **(b)**

Plate 6: Development of irrigation scheme (a) an old canal (b) sign post showing on-going project on construction of irrigation scheme at Njage Village in Kilombero District, Tanzania.

According to one key informant at the construction site, it was reported that the irrigation scheme would include building diversion weirs and canal control structures. Therefore expected that large area will be covered by irrigation schemes in the village and therefore the majority of the households will have a piece of land that is irrigated. The regional report in the National Sample Census of Agriculture (URT, 2012b), showed that currently irrigation farming in Kilombero District covered about 2 939 ha, which is equivalent to 16% of the total irrigated area in Morogoro Region. Similar irrigation practices are also done elsewhere in Tanzania (Mkavidanda and Kaswamila, 2001; Maganga *et al.,* 2004; Msuya, 2009) with different management mechanisms. Presence of irrigation schemes increasing adaptive capacity to both households at adjacent and distant to the IFR.

During FGDs, it was reported that the Kilombero Plantation Limited (KPL) was among the organisations that enhanced adaptive capacity of the households in the study area. The KPL which was reported to operate her activities in Njage Village, was involved in building capacity to households on how to cultivate rice using modern techniques including planting rice using seedlings, use of improved rice and maize varieties, use of pest and disease resistant seeds, use of fertilisers and relevant pesticides. According to URT (2012b) Kilombero District had the largest planted area applied with inorganic fertilizers (70% of the 37 701 ha), herbicides (52%, of the 79 137 ha) of the total area under such practice in the region. Other organizations reported to increase adaptive capacity of the households were the Plan International and Kilombero Valley and Development organization (KIVEDO), through German Federal Ministry for Economic Cooperation and Development (BMZ) support (Plate 7). This organization operated her activities at Miwangani, Mpofu and other villages in Mbingu and Idete wards. It dealt mostly with development activities in the village like building schools, roads, water well construction, supporting orphans as well as raising awareness on different disasters, which are due to climate change impacts.

Plate 7: A sign post showing different organisations dealing with climate change adaptation projects in Kilombero District, Tanzania.

On the other hand, non-farming adaptation strategies for climate change were revealed to include livestock rearing, fishing, petty business, casual labour, remittances, carpentry and masonry. It has been pointed out that non-farming is a form of livelihood diversification, which draws attention to variety of dissimilar income sources (Ellis, 2000; Kamanga *et al.,* 2009; Shemsanga *et al.,* 2010; Nindi and Mhando, 2012). According to Ellis (2000) livelihood diversification is defined as the process by which households construct a diverse portfolio of activities and social support capabilities for survival in order to improve their standard of living.

To be involved in various non-farming activities some of the households either individuals or groups were reported to be eligible to get financial assistance from different micro financial institutions (MFIs) that existed in the study area.

The following MFIs were noted to function in the study area, including Village Community Banks (VICOBA), Savings and Credit Cooperative Societies (SACCOS), Youth Self Employment Foundation (YOSEFO), FINCA Tanzania, and PRIDE. YOSEFO brings together youth, giving them life skills that can be used to improve their living standard using available resources. Formal MFIs such as FINCA Tanzania and PRIDE (Plate 8) provide affordable loans to households' livelihoods improvement.

Plate 8: **A sign post showing presence of financial institutions around study villages in Kilombero District, Tanzania**

4.5.3 Socio-economic factors influencing adoption of local climate change adaptation strategies

The results showed that, household size (X_2), duration the respondent lived in the study area (X_3), land ownership (X_5) and household income (X_6) were the socio-economic variables that positively influenced adoption of local adaptation strategies and were significantly at 5% probability level (Table 22). Age (X_1) of the respondent influenced adaptation strategies negatively however was significant at 5% probability level. Education level (X_4) influenced adaptation strategies positively but not significantly at 5% probability level. Forest access rules (X_7) influenced adaptation strategies negatively and insignificantly.

Table 22: Socio-economic factors influencing local climate change adaptation strategies in Kilombero District, Tanzania

Independent variables	One to three adaptation strategies						More than three adaptation strategies					
	β	S.E	Wald	df	Sig.	Exp(β)	β	S.E	Wald	df	Sig.	Exp(β)
Intercept	.490	.776	.399	1	.528	-	-20.921	4.939	17.940	1	.000	-
Age (X_1)	-.038	.016	5.819	1	.016*	.963	-.045	.127	.124	1	.725	.956
Household size (X_2)	.400	.081	8.569	1	.003*	1.269	.400	.332	1.451	1	.228	1.492
Residence period (X_3)	.007	.012	6.815	1	.009*	1.031	.007	.097	.005	1	.941	.993
Education level (X_4)	.464	3.059	1.235	1	.266	.629	16.251	3.059	.000	1	.998	.000
Land ownership (X_5)	16.399	.000	1.023	1	.312	.575	16.399	.000	.000	1	.000*	1.325
Household income (X_6)	.017	.042	3.093	1	.049*	1.031	.067	.097	.005	1	.941	.993
Forest access rules (X_7)	-.002	.385	.000	1	.996	.998	-1.655	7.261	.000	1	.998	1.5397

Note: Cox and Snell R-Square = 0.561; Nagelkerke R-Square = 0.642; β = regression coefficients which stand for the odds ratio of probability of success to the probability of failure, SE = standard error of the estimate, Wald statistics = Wald statistics denotes relationship between dependent and independent variables; df = degree of freedom, Sig. = significance or p values, Exp (β) = odds ratio (probability of success over probability of failure); *Statistically significant at $p < 0.05$ level.

Age of the respondent

In this study, the majority of the respondents (56%) were in age group that ranged between 31 – 50 years old (Table 23), with a mean age of 44.82±1.03 years.

Table 23: Age characteristic of respondents in Kilombero District, Tanzania

Age group	Response (%)	
	HHs adjacent to IFR (n= 157)	HHs distant to IFR (n = 58)
20 – 30	17	14
31 – 40	33	30
41 – 50	27	23
51 – 60	9	13
61 and above	14	20

A number of adaptation strategies were observed to decrease as the individuals in the household approaches old age. The negative beta coefficient (β) indicated that as the age of the respondent increases, there is likelihood of decrease in the number of adaptation strategies (Table 22).

Findings from this study are inconsistency from other literatures. Dolisca *et al*. (2006) explained that, age relates significantly to farmer's decisions to adopt new technologies, thus affects adaptation to climate change. Similarly, according to Tazeze *et al.* (2012), as age of the household head increases, the person is expected to acquire more experience in weather forecasting that helps increasing the likelihood of practicing different adaptation strategies to climate change. The differences observed could be due to difference in life expectancy between Tanzania compared to Ethiopia and Haiti.

Household size

Household size determines per capita livelihood diversification hence contribution to people's adaptive capacity (Elis, 2000; Gbetibouo, 2009). Results revealed that household size had positive beta coefficient (β) suggesting significant influence ($P \leq 0.05$) on the number of adaptation strategies a household can contain (Table 22). That implied a unit change in household size increases likelihood of increasing the number of adaptation strategies.

It is anticipated that, a household with large number of individuals increase adaptive capacity to climate change (Nhemachena and Hassan 2008; Aymone 2009). A study by Giliba *et al.* (2010) in Babati district and Njana *et al.* (2013) at Urumwa Forest Reserve in Tabora region showed that household sizes facilitated the contribution of the livelihoods of local people adjacent to forests resources. The study has recorded a mean household size of 4.9±0.17 (Table 24) people indicating the probability of increasing work force that will eventually be able to undertake various livelihood activities.

Table 24: Population characteristics of respondents in Kilombero District, Tanzania

Study strata	Population size	Household size
HHs adjacent to IFR	6 525	4.8
HHs distant to IFR	2 545	4.9
Total	9 070	
Average	3 023	4.9

HHs = Households

Similarly, Gbetibouo (2009) in South Africa revealed that a large household is more willing to choose the adaptation options that are labour intensive such as soil conservation techniques, developing irrigation schemes and chemical treatments. Household size determines per capita livelihood diversification hence contribution to people’s adaptive capacity (Ellis, 2000; Gbetibouo, 2009).

Residence period

The period the head of household lived in the study area had significant positive beta coefficient (β) ($P \leq 0.05$), suggesting that it influences adoption of developed adaptation strategies. This implied that, a unit change in resident period increases likelihood of increasing the number of adaptation strategies (Table 22). However, there were no significant differences ($P \leq 0.05$) in residential period when more than three adaptation strategies were involved. It is speculated that people who lived in the study area for a long time because of increased experience, knowledge and accessed information on adverse climate change effects probably developed more adaptation strategies. According to Ellis (2000) and Nhemachena and Hassan (2008) people living for a long period in a certain area are able to develop large number of adaptation strategies.

Land ownership

Land ownership is about securing right to long-term access to land and their benefits (Lutz *et al.*, 1994). Results showed that land ownership had positive beta coefficient (β) suggesting that it influences the number of adaptation strategies especially when people decided to have more than three options (Table 22). The variable was not significant ($P \leq 0.05$) when people opted to have two to three adaptation strategies. This could probably be associated with the security on land ownership. Secured ownership enables households to develop various adaptation strategies. Farmers who own land are more likely to invest in various adaptation options, including crop and livestock management practices and water conservation. Studies have shown that land ownership encourages the adoption of various technologies linked to land including irrigation, drainage, tree planting and crop diversification (Lutz *et al.,* 1994; Shultz *et al.,* 1997; Nhemachena and Hassan, 2008).

Findings in this study indicated that most of the households adjacent and distant to IFR had security to land, however the land owned was not enough to carry out other adaptation options. For example setting aside a piece of land for tree planting was not of priority because of land scarcity. On average one house owned land of about 1.3 to 1.7 hectares, which were mainly used for crop cultivation. As the land in the study was scarce, study proposes that households could adopt agroforestry system by integrating crops and trees on the same piece of land in order to maximise value of the available land.

Household income

Table 22 indicates that household income had positive beta coefficient (β) suggesting that the variable has influence on adoption of adaptation strategies households developed. This indicates that, a unit change in this variable increases likelihood of increasing the number of adaptation strategies, which was statistically significant ($P \leq 0.05$). It is argued that households with higher income and greater assets are in better position to adopt new farming technologies than those with less. Findings in this study are similar to that of Deressa *et al.* (2009) and Tazeze *et al.* (2012) who found that household income had significant impact on increasing adaptation strategies, which include, use of different crop varieties, irrigation technologies, early cultivation and changing planting dates.

Education level

Results in Table 22 have also revealed that education of the respondent had positive beta coefficient (β) suggesting that it influences the number of adaptation strategies, though was not statistically significant ($P \leq 0.05$). Studies by Adesina and Forson (1995) and Daberkow and McBride (2003) showed that educated and experienced farmers have more knowledge and information about climate of a particular area, thus enabling individuals increase the probability of adopting new technologies when adversely affected.

Similarly, Tazeze *et al.* (2012) found that literate farmers are more likely to respond to climate change by making best adaptation options based on preferences and influences of individual decision making. In this study the majority (75%) of the respondents were literate at a level of primary education, indicating that they were able to practice out various adaptation options based on their ability to acquire appropriate training thus gaining skills and knowledge, if availed.

Forest access rules

Forest access is important when it comes to the issue of livelihood contribution to households by increasing their adaptive capacity. The rules and regulations put on access to the forest resources often influence the livelihoods of the households. Results showed that forest access rules had negative beta coefficient (β) in the study area suggesting its less influence on the number of adaptation strategies a household can contain (Table 22). As the beta coefficient of this variable was negative, it implied that a unit change decreases the likelihood of increasing the number of adaptation strategies. In the study area, people declared that, recently formal collection of forest products from Iyondo Forest Reserve and in some areas in the grassland in Miwangani Village was not granted because were within the Kilombero Valley Floodplain Ramsar Site, and thus access has been illegal. It was further noted that households were not only restricted to collect forest products but also free entrance, unless with formal permission (Plate 9). Signposts were put in place in 2013 indicating reinforcement of the rules for access to the forest, the situation that could increase stress to households, and thus reduce their adaptive capacity.

Plate 9: **A signpost at the Kilombero Nature Reserve ordering prevention of forest fires and trespassing.**

For a long time, households have been passing through the forest on foot when moving from Kilombero to Kilolo district and vice versa. Currently, the available free connection is through the highway that passes Kilosa District at Mikumi through Ifakara Town. Therefore, this seems to have limited the socio and economic relationship that existed for a century, noting that the majority of the households residing in the study area were migrants from Kilolo District. Thus, this implies that the adaptive capacity of the households adjacent to IFR could probably be reduced if the rules and regulation will remain stringent.

CHAPTER FIVE

5.0 CONCLUSIONS AND IMPLICATIONS FOR RESEARCH AND POLICY

5.1 Overview

The aim of this thesis has been to enhance the understanding of the role of Non-Timber Forest Products (NTFPs) in climate change adaptation with a case study of households adjacent and distant to IFR in Kilombero District, Tanzania. Kilombero District in Tanzania is prone to diverse climatic stresses, including frequent floods, dry spells during rainy season and extreme heat, which have adverse effects to the livelihoods of many households. The role of NTFPs in the way that households adapt and achieve livelihood security in the face of climate stressors is neither well known nor documented. Many adaptation studies in this country have focused specifically on agricultural production or livelihoods in semi - arid areas (Lema and Majule, 2009; Mongi *et al*., 2010; Kangalawe and Lyimo, 2013), yet there is increasing evidence that households engage in many activities beyond agricultural production and that forest products are particularly important in how they could manage socio-environmental stresses.

The study has generated empirical evidence on NTFPs and climate change adaptation that can inform different existing national strategies, programmes and policies within the forestry and natural resources related sectors in Tanzania. Critically, the study argues that NTFPs are used for different types of livelihood capital assets, closely linked to people's portfolio of wider strategies, that are often used for trade and gaining financial capital not only household subsistence. However, the rules governing the forest access often impede people's adaptive capacity, as collection of NTFPs has been restricted. Findings in chapter four have revealed that upgrading management status from Iyondo Forest Reserve to Kilombero Nature Reserve was another stress to households. However, it was revealed that currently there is informal arrangements that allow households to enter into the forests to collect some few NTFPs like dried firewood, mushrooms, fruits and wild vegetables, even though could not be sustainable.

The study further found that NTFPs are important to people both adjacent and distant to forests. Findings suggest that policies aimed at supporting rural adaptive capacity need to address the rules and social factors that impede access and support the way that NTFPs contribute to various types of livelihood capitals and the way they relate to other strategies apart from NTFP. This has implications to policy and decision makers on how to formulate programmes, policies in particular, both agricultural and adaptation that need to support NTFPs as part of rural livelihood security. Theoretical contribution of the thesis to the knowledge as NTFPs formed part of the strategies that contributed to other livelihood capital assets in the SL framework including financial, physical and human to manage adverse effects of changing climatic condition including global climate change. However, the thesis argument is on important aspect of the interaction between vulnerability and biodiversity is that access to resources by vulnerable populations is as important as the conservation of biodiversity. Policy and decision makers could consider both aspects of access to NTFPs for enhancing adaptive capacity of households as well as biodiversity conservation through established enabling rules.

This chapter describes the main conclusions from the study, discussing their main implications for future research and policy. Conclusions are in four main sub-sections, following research specific objectives set out in chapter one. The first is on households' perceptions of the effects of climate change. The next two sub-sections describe key findings regarding availability, use pattern and the economic value of NTFPs, in particular those that were of priority for households' climate change adaptation strategies.

The fourth sub-section is on roles of priority NTFPs, other strategies to adapt to climatic stresses and longer-term changes in climatic conditions at household level. The final part of the chapter discusses the implications of the findings for future research and policy.

5.2 Conclusions

(a) Household level perceptions of the effects of climate change

The study has revealed that changes in climatic conditions are affecting the livelihood security of households adjacent and distant to IFR in Kilombero District. These changes, in terms of increasing dry spells, floods, heavy rains and extreme heat, are associated with climate change. As shown in chapter 4, section 4.2.2, where analysis of quantitative household survey and focus group discussion data showed that majority of households adjacent and distant to IFR perceived the climate condition of their area to have changed as indicated by increased temperature and unpredictable rainfall with delay in onset or cessation of rain sometimes with high intensity.

The above perceptions were in line with the existing meteorological data that has indicated rainfall to be unpredictable during the past three decades (1980 to 2010). The findings contribute to empirical evidence that people in humid areas are also experiencing adverse impact of climate change on their livelihoods similarly to what is already known from arid and semi –arid areas of Tanzania.

This understanding is particularly important because research and policy have paid most attention to the vulnerability of rural populations in arid and semi-arid areas. This study shows that droughts and diverse climatic stressors are important for populations in the less dry areas including Kilombero District. This finding is critical for policy implementation; since livelihood of people from different agro ecological zones of

Tanzania are insecure in the face of adverse effects of climate change; attention needs to be directed at enhancing adaptive capacity among populations in a wide range of geographical locations particularly to the households.

(b) Availability and use of NTFPs under the current change in climate

Three out of 12 investigated NTFPs namely; firewood, medicinal plants and thatch grasses were identified during FGDs to be of priority. They were of priority because of their immediate importance in supporting households adjacent and distant to IFR to manage adverse effects of changing climatic conditions. These products were used for subsistence and trade towards enhancing adaptive capacity to offset adverse effects of changing climatic conditions. Firewood and medicinal plants were relatively highly available in households adjacent to IFR than those distant. Thatch grasses were highly available in households distant to IFR. NTFPs assessment in IFR indicated firewood and medicinal trees species to be relatively high implying availability of these resources for use. Furthermore, the observed regeneration indicated potential of some important tree species to be cultivated on farms by households. Importantly, household survey data indicate a prominent shift in use pattern of priority NTFPs e.g. firewood and thatch grasses from subsistence to trade for income generation to account for various human needs including domestic energy, education, health services and construction. It was revealed that large amounts of priority NTFPs were traded because of reduced household income from conventional livelihood activities, which are currently affected by adverse effects of climate change stresses.

The above findings show that with changing climatic conditions, natural capital such as forest products are often turned into financial capital, rather than being used directly for household consumption, as previously assumed. This finding is important for our understanding of how households in other areas of Tanzania and rural Africa too, build their livelihoods. Efforts to support adaptive capacity among such populations must facilitate the way that vulnerable groups derive the financial capital derived from NTFPs in addition to the subsistence benefits. However, it is also important to know which households and who within the households is engaging in NTFP collection. For example firewood collection was done by both men and women for both subsistence and trade purposes, unlikely previous studies that indicated that women mainly did firewood collection, as was a culture to most of the tribes in Tanzania. The current study now informs us that there is transition of some activities that were previously gender biased, are now performed by both men and women.

(c) Economic value of selected priority NTFPs

The economic value of studied priority NTFPs for both substance use and trade at a discounting rate of 10% was obtained from household survey data. The economic value of selected priority NTFPs were collected from Iyondo Forest Reserve, village forests and the grasslands. The economic value of priority NTFPs, at a discounting rate of 10% was mainly contributed by firewood, followed by thatch grasses and medicinal plants. High contribution of firewood to the economic value is associated with high collection of the product due to daily demand, unlike for medicinal and thatch grasses. Due to this value, the majority of the households adjacent and distant to IFR seem to rely on firewood as immediate sources of income when conventional livelihood activities were adversely affected by climatic stresses. The main body of understanding has so far focused on the value of prominent forest products like timber, and the impacts of climate change on such resources.

(d) Roles of priority NTFPs, and other strategies to manage adverse effects of changing climate at household level

The use of priority NTFPs formed part of a wide set of connected strategies to manage climatic stresses. NTFP use was combined with both farm and non-farm strategies, including crop diversification, changing cropping calendar, adopting modern farming techniques, livestock rearing and fishing. Use of NTFPs by households was important not only as a source of cash income to afford for health services and education for children but also to strengthen other household adaptation strategies including farm preparation, buying improved food crop seed varieties, weeding, herbicides and pesticides. The households adjacent and distant to IFR used the priority NTFPs to enhance their adaptive capacity to climatic stresses. In addressing the climatic stresses and eventually to the long-term change effects, the majority of the respondents adjacent and distant to IFR indicated that firewood and medicinal plants contributed to both human and financial livelihood capital assets. Thatch grasses contributed to physical and financial livelihood capital assets.

These findings elaborate understanding of how NTFPs could contribute to livelihood capital assets and play in how different households manage environmental stresses. NTFP use in the context of local adaptation strategies must therefore be understood as fulfilling multiple roles and functions that complement and strengthen other non-forest based strategies rather than contributing only to subsistence or single types of capital. The observed contribution of priority NTFPs to livelihood capital assets in this study provides better understand of the multidimensional and dynamic nature of local adaptation and how it can be supported in policy interventions.

5.3 Implications for future research and policy

(a) Implications for future research

The findings described above have several implications for future research. Figure 9 outlines how the role of NTFPs in household adaptation can be understood in terms of the sustainable livelihoods framework. The study findings suggest that several elements of the interaction between NTFPs, livelihood strategies and household adaptation need to be more explicitly explained. The interaction between transforming structures, influence and access, and use of NTFPs is illustrated with the overlap between these spheres. In this overlap, what is particularly important is that households use NTFPs, which are part of the livelihood assets to enhance their adaptive capacity to climate change shocks and stresses. However, sustainable use of NTFPs is influenced by transforming structures and process, which facilitates access to the resource. The following are the implications for future research emanating from this study:

First, the study has revealed that both households adjacent and distant to IFR perceived changes in climatic conditions in terms of increasing dry spells, floods, heavy rains and extreme heat. Different to other studies in dry areas in Tanzania where drought has been prominent, the livelihoods in Kilombero District are faced with both dry spells and floods at different times. Kilombero District is different from dry areas in Tanzania in such a way that it experiences humid climate and geographically located into a flood plain zone, thus being at high risks to climate stresses. The noticed dry spells in the study area can in future lead to drought in the area, which will have much adverse effects to the livelihoods of the people. This calls for interventions on how to manage both dry spells and floods as they both appear and have adverse effects on the livelihoods. The study show importance of households' perceptions of climate change and that understanding is important to recognise the adverse effects of shocks and stresses on livelihoods. It is understood that people's perceptions indicate the importance of different types of shocks and stress that may not be objectively measured through meteorological data. More research is important that will focus explicitly on perceptions in order to understand which climate stresses have the most impact on both households adjacent and distant to IFR, and why. Local climate knowledge is another aspect that needs to be explicitly written into SL framework.

Second, the study has revealed availability and use of priority NTFPs for both subsistence and trade in Kilombero District. Priority NTFPs included firewood, medicinal plants and thatch grasses. Trade of the priority NTFPs was revealed to contribute to the livelihoods of the households. The NTFPs addressed well capital assets in the SL framework, therefore translating role of the NTFPs to livelihood strategies. The SL framework has been useful to this study as it includes livelihood capital assets in the framework in which the NTFPs are within the natural capital. However, the transforming structures and processes in the SL framework were observed to hinder access to the resources, thus increasing stresses to households. Importantly, access to the resources could be regulated in order to realise the livelihood outcomes. The possible negative as well as positive way that transforming structures and processes may affect access to resources needs to be conceptualised in the SL framework in Tanzania and elsewhere in Africa.

As the priority NTFPs were revealed to contribute significantly to the livelihood capital assets, more research could be important to be carried out to understanding contribution to the livelihood capital assets of other NTFPs not studied. Further research could also focus on ecological study that will focus on effects of shift of rain seasons on crops production and availability of some NTFPs in the study area.

Third, the priority NTFPs were revealed to have high economic value indicating that they can contribute significantly to the livelihoods of the households. This informs policy and decision makers that economic value of forests is also from NTFPs as well as the conventional products ‘timber’. In most of the forests and woodlands in Tanzania timber harvesting is being prohibited, to allow conservation of some important NTFPs tree species for human use. Therefore, based on the current situation from different forests and woodlands, NTFPs could be sustainably harvested in different management regimes. The current economic value of the studied priority NTFPs was analysed from annual quantities collected from different seasons, in which the value of the products was harmonized. More research could be undertaken to compare the economic value of some NTFPs in rainy and dry seasons.

Fourth, use of priority NTFPs as well as other non-NTFPs formed part of a wide set of related strategies to manage climatic stresses. The majority of the households used priority NTFPs because most of them were available and reliable throughout the year. In addition, trade of priority NTFPs to get cash income was carried out in order to be able to engage in other local strategies. This indicated that priority NTFPs had multiple uses one including the direct benefits that are the subsistence use and cash income to afford other households’ services including health and education. The indirect contribution of the priority NTFPs was on use of the gained cash income to enhance other local adaptation strategies are exemplified under Section 5.2.4. Both direct and indirect contribution of the NTFPs to local adaptation is captured in the SL framework through livelihoods capital assets in order to realized livelihood outcomes including improved food and health security as well as increased well-being. The framework does not, however, capture the role of gender and power distribution within the household. An important insight given the gender-based roles that prevail in the household and the distribution and kind of work undertaken by males and females in many contexts is pertinent to be addressed explicitly. This component needs elaboration in future research and theoretical development so that it captures gender role in distribution of activities and income among males and females at household level. As the income from NTFPs was invested in other strategies as well, more research could be established to evaluate the exact extent of contribution of NTFPs to other local adaptation strategies.

Lastly, the main research findings described above, contribute to further conceptual and theoretical development of the SL framework approach (Fig. 9). The thesis findings suggest four key issues for further conceptualisation in the SLF. First, the positive and negative roles of transforming structures and processes; second, the role of markets and NTFP collection for subsistence and cash income purposes; third, gender roles and power relations; fourth technology, such as those adding value to NTFPs. The conceptualisation encompasses how the interaction between vulnerability and biodiversity shapes livelihoods processes for households adjacent and distant to IFR. The new aspects of the framework influence sustainable subsistence use and trade of NTFPs (Fig 9). NTFPs formed part of the strategies that contributed to other livelihood capital assets in the SL framework when used sustainably for subsistence and trade to manage adverse effects of climate stresses and shocks including floods, dry spells during rainy season and heat stress.

Access to the forests and wooded grasslands by vulnerable populations is as important as the conservation of biodiversity. Both access to forests and grasslands as well as conservation of biodiversity are important to adaptive capacity. The potential synergies and conflicts between these two aspects of NTFPs are managed by rules and regulations, indicating the importance of transforming structures. Market access and their roles by households is another aspect that the thesis emphasizes, as it is not explicitly stated under the SL framework (Fig. 1), chapter one, section 1.4. The study has found that market roles and access is an important aspect in enhancing adaptive capacity as it influences sustainable subsistence use and trade of NTFPs, which are part of the livelihood strategies.

The role of gender and power distribution among members in collection and marketing of priority NTFPs is an important aspect for enhanced adaptive capacity. Moreover, the SL framework (Fig 1) does not adequately describe the adoption of appropriate technologies including value addition of NTFPs for this case. The study argues that appropriate technologies are important for increasing value of the products as it has implications on the market value and thus enhancing adaptive capacity of the households (Fig. 9).

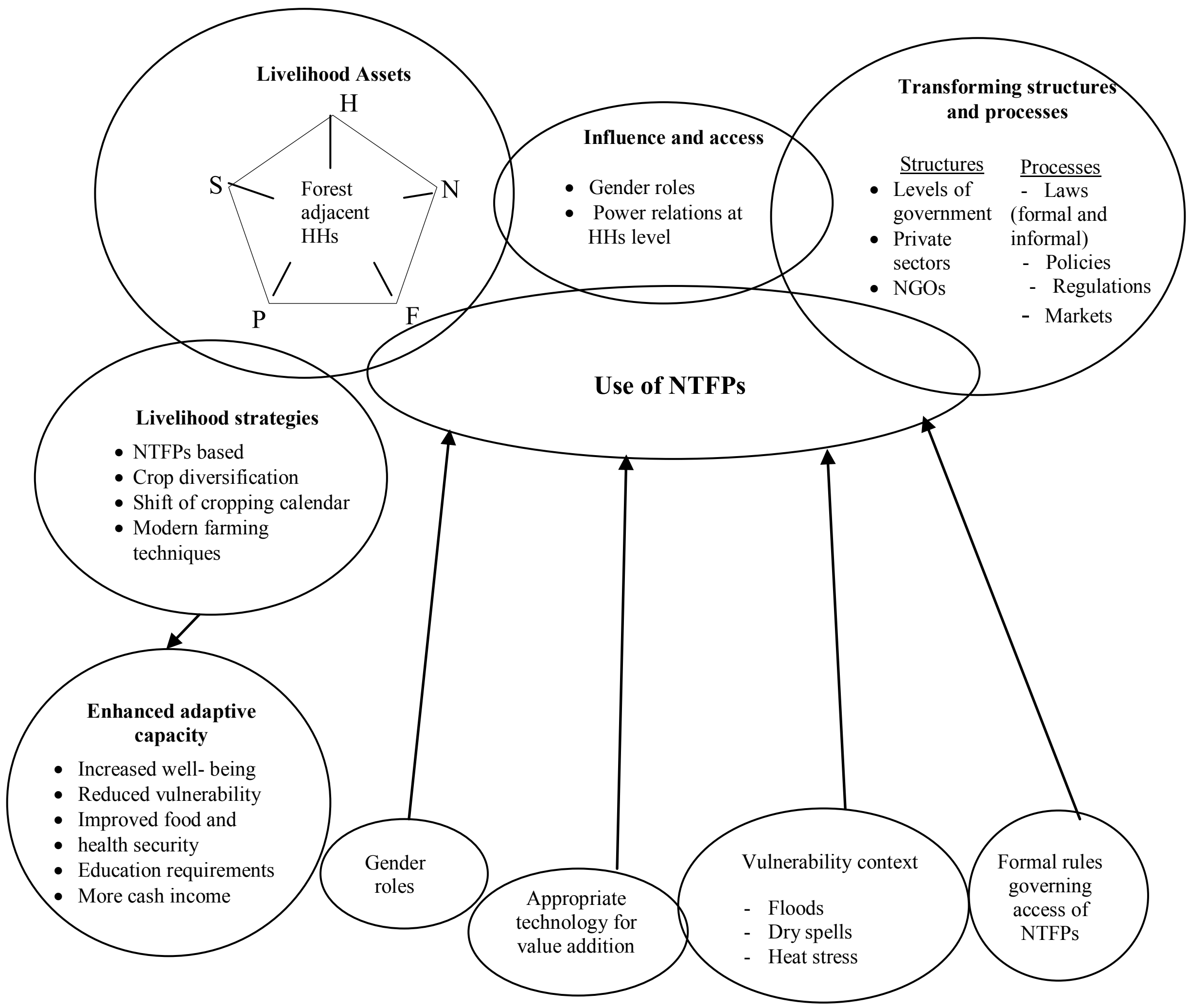


Figure 9: Study findings and analytical framework

Key: F=financial capital; H=human capital; N=natural capital; P=physical capital; S=social capital; HHs = Households

(b) Implications for policy

From the study, the following are the relevant policy implications:

First, the study has documented that households adjacent to IFR in Kilombero District are collecting NTFPs illegally from the IFR because the type of management regime does not allow human activities.

Together with this, it was as well noted that within the villages' land, there were remnants of forests that could be managed through formal processes into village forest reserves.

Establishment and or strengthening management of existing village forest reserves in which households will have full access is important for sustainable utilization of NTFPs, thus enhancing their adaptive capacity. The Kilombero District Council could facilitate preparation of land use management plan that will enable various activities to be carried out in the area sustainably. The study proposes that, the established village forest reserves could be managed through community based forest management (CBFM), a management regime that will allow total participation of households in decision making about sustainable forest management.

Second, the study has revealed existence of important indigenous tree species that were also reported to have multiple uses. The trees were also found on some farms, thus could be promoted to increase product availability. On farm, cultivation of potential NTFPs trees species is crucial for promotion of its availability in order to ensure sustainable supply of NTFPs in markets. This will in turn enhance more the adaptive capacity of the households adjacent than distant to IFR to face both current and future adverse effects of changing climatic conditions. It is therefore important to establish village rules that will enforce households to practice in or ex-situ conservation, whereby at least four stems can be established per each acre planted with other agricultural crops. Policy and decision makers in Kilombero District could facilitate this process within their annual plans and cooperate with research and academic institutions as well as development partners to provide expertise on this subject.

Third, the study found that forest households lack skills and knowledge about value addition and marketing of the NTFPs collected. This situation has led to low market value of the products. Capacity building to households on priority NTFPs value addition and strengthening its markets is pertinent for improved income and eventually increase adaptive capacity to adverse effects of the changing climatic conditions. In addition, capacity building on marketing of the products could include establishment of collection/trading centres in order that it becomes easily for price monitoring as well as control of the quality of the products. To achieve this, the government through the Kilombero District Council could incorporate capacity building activities into annual plans in order that relevant trainings are done to forest adjacent households.

Last, livestock rearing, fish farming and petty business were among the off-farm livelihood activities practiced by the households in Kilombero District. This is a form of livelihood diversification in order to cope with adverse effects of climate change but which could in the long term potentially, lead to enhanced adaptive capacity. The Kilombero District Council through Ward Counsellors could come up with policies that support households to establish small scale off-farm projects. For example could provide some subsidies on inputs so that majority of them afford such projects. In the same vein, the district government could ensure that extension services are strengthened and provide free to all people with different livelihood activities. Such situation will lead to increased adaptive capacity to current climate change adverse effects.

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APPENDICES

Appendix 1: Focus group discussion checklist

1. Have you observed any climate stresses in your area?
2. What kinds of climate stresses you have observed?
3. Are there any adverse effects resulting from climate stresses?
4. Are there any vulnerable socio groups due to climate stresses observed?
5. How do people in the community currently adapt to the effects of climate stresses?
6. Are these types of climate stresses observed are due to climate change?
7. How are the NTFPs used as adaptation strategy?
8. What are the NTFPs currently available in your area?
9. Which of the NTFPs are of priority in adaptation to experienced climate stresses?
10. Where are the NTFPs collected?
11. Who are involved in collection of NTFPs?
12. What is the availability and access of the NTFPs?
13. What is the trend of availability comparing to the past? Increasing/decreasing?
14. Do you have any general comment on use of NTFPs as adaptation strategies?
15. How do local institutions enhance climate change adaptation?
16. Are there any political structures available that enhance climate change adaptation?

Appendix 2: Checklist for key informant interviews

1. Have you observed any climate stresses in your area?
2. What kinds of climate stresses you have observed?
3. Have you experienced occurrence of new diseases to either human, crops or livestock?
4. Which of the livelihood assets are vulnerable due to climate stresses?
5. How do people in the community currently adapt with the effects of climate stresses?
6. What is the trend of availability and access of NTFPs comparing to the past?
7. How power dynamics have shaped access to resources over time?
8. How are the NTFPs used as adaptation strategies to climate stresses?
9. Have there any change in use of NTFPs resources over time?
10. Are there any policies governing resource use?
11. Are these types of climate stresses observed are due to climate change?
12. How local institutions enhance climate change adaptation?
13. Have local institutions been changing over time?
14. Are there any political structures that enhance climate change adaptation?
15. What is your general comment about use of NTFPs as adaptation strategies against climate change effects?

Appendix 3: Questionnaire for household survey

A. General information

1. Region …………………., 2. District ………………….., 3. Ward……..………….. 4. Village…………..………… 5. Sub-Village ……………………, 6. Respondent No…………, 7. Gender: Male ………. male …………; 8. Age ………. years
9. Marital status (single/married/widow/separated/divorced)……………... Other (specify)……………………………………………………………………...
10. Family size …………………………..…………………………………
11. How long have you lived in this place? ……………………..….………years
12. Place of origin: (i) In the village (ii) Outside the village but within the district (iii) Outside the region (iv) Outside the country
13. If migrant, what prompted you to migrate to this area? ....
14. What is your level of education?
    - (i) No formal education
    - (ii) Primary education
    - (iii) Secondary education
    - (iv) Post-secondary education
    - (v) Others (specify) ……………………………….…………
15. What is your occupation?
    - (i) Peasants
    - (ii) Employed
    - (iii) Business
    - (iv) Others (specify)………………………..…………………..…….
16. The house in which you live is:
    - (i) Your own
    - (ii) Rented
    - (iii) Borrowed
    - (iv) Others (specify) ………..…………………………………
17. If the house you live is your own, when was it built?.............................. and which materials were used?..
18. Do you cook with:
    - (i) Firewood
    - (ii) Charcoal
    - (iii) Firewood and charcoal
    - (iv) Gas
    - (v) Charcoal and gas
    - (vi) Others ………..………………………..………………….
19. What is your Primary and Secondary economic activity in your household?

S/N	Economic activity	Primary economic activity		Secondary economic activity	
		Monthly income	Annual Income	Monthly income	Annual income
1	Agriculture (crop production)				
2	Livestock keeping				
3	Wage employment				
4	Casual labour				
5	Petty business (kiosks, food vending)				
6	Crop trading				
7	Beekeeping				
8	Making and selling bricks				
9	Making and selling charcoal				
10	Collecting and selling firewood				
11	Collecting and selling edible fruits				
12	Collecting wild plants				
13	Art and Craft work (specify)				
14	Hunting				
15	Tourism				
16	Fishing				
17	Masonry				
18	Carpentry				
19	Mechanics				
20	Others (Specify)				

20. What is the size of the land you cultivate? ……………………………..acres
21. What is the tenure of the land you cultivate?
    (i) Own
    (ii) Rented
    (iii) Others………………………………..………………………
22. What is the distance from the house in kilometres/miles to the farm?..………………

23. Does your family have access to forest resources? ………………………….…………
24. How far is this area from the house/measured in terms of distance ………… (m) measured in terms of time(in minutes walking) …………………………...……. (min)

B. Non-Timber Forest Products (NTFPs), Collection and Use

25. Which of the NTFPs do you collect?...
26. Among the NTFPs, which ones do you collect?...
27. How frequently do you usually collect NTFPs?
    i. Every day
    ii. Every week
    iii. Every month
    iv. A certain period of the year

v. Few times a year
vi. Not this year
vii. If a certain period of the year, when is this?..
28. Where are the NTFPs collected?
(i) Forest
(ii) Bush land
(iii) Woodland
(iv) Agroforestry land
(v) Home gardens
(vi) Others…………………………………………………………………….
29. How much of the NTFPs you collect per day/week (state unit) ....
30. What is the use of the NTFPs you collect?
(i) For subsistence
(ii) For trade
(iii) Subsistence and trade
31. What is the availability of the NTFPs you collect or sale?
(i) Highly available
(ii) Available
(iii) Moderately available
(iv) Not available
32. If the NTFPs are not available, please explain the cause ………………………………
33. Among the NTFPs collected which one is used for subsistence and trade?

SN	NTFP	Purpose of collection	
		Subsistence	Trade

34. How much of the NTFPs are required for your household consumption per week/month? (State unit)

SN	NTFP	Amount required (week/month)	Units

35. How are the NTFPs used as adaptation strategies against effects of climate stresses?...
36. Is there any change in use of NTFPs resources over time? ....
37. Are there any power dynamics that shape access to the NTFPs resources over time?...

C. Perception on climate change, vulnerability and Adaptation
38. Do you experience any climate stresses in your area?
(i) Yes
(ii) No
39. What are the types of climate stresses you have observed for the past 30 years?...
40. What is the trend of rainfall for the past 30 years?
(i) Increasing

(ii) Decreasing
(iii) Persistence
(iv) Not sure ……………………………………………………………………………...

41. If the rainfall has been decreasing, state the adverse effects to livelihoods ………………………………………………………………………………………...…
42. If the rainfall has been increasing, state the adverse effects on livelihoods ………………………………………………………………………………………

43. What is the trend of temperature for the past 30 years?
    (i) Increasing
    (ii) Decreasing
    (iii) Persistence
    (iv) Not sure …………………………………………………….………
44. If the temperature has been increasing, are there any adverse effects on livelihoods?..
45. If the temperature has been decreasing, state the adverse effects on livelihoods? ……………………………………………………………………
46. Has there been a particularly climate stressful year: this year?................................. last year?.......................the last five years?.................. the last 10 years?.....................
47. Are there any vulnerable livelihood assets in your area, due to climate stresses?
    (i) Yes
    (ii) No
48. If yes to Q.47. Please mention them ………………………..……………………..
49. Are these types of climate stresses observed are due to climate change?
    (i) Strongly disagree
    (ii) Disagree
    (iii) Neither agree nor disagree
    (iv) Agree
    (v) Strongly agree.………….....................………………….………………...
50. What are the adaptation strategies developed against the effects on climate stresses?..
51. How are the NTFPs used as adaptation strategies against the effects on climate stresses?...
52. Do you have any general comment regarding use of NTFPs as adaptation on climate stresses? …………………..……………………………………………………………

Appendix 4: Parameters and indictors used to assess community vulnerability perception in the study area

Exposure

Parameters	Indicator(s)
Temperature	Increased in number of hot days including hot waves intensity Cold days decreased (short winter) including cold waves intensity
Rainfall	Short rains erratic and unreliable (short duration with high intensity or vice versa) Long rains decreased in intensity and have become uncertain Reduced duration of long rains (delay onset and early cessation of rains) Lack of monthly rains in dry season
Climate induced disasters	Frequency of floods in the areas Frequency of dry spells in the area Frequency of wild fires Frequency of lightings Frequency of winds Frequency of hailstones
Livelihood activities	Changes in planting dates of crops Prevalence of crop pest and diseases Percentage of population living in floodplain areas Rain-fed cropped area
Physical information	Decreased water sources in dry season Disruption of road communication between villages

Sensitivity

Parameter	Hazard(s)	Indicator(s)
Agriculture and food security	Dry spells	Loss of crop production
	Floods	Loss of productive land
	Wind & Hailstones	Crops lose flowers, decline in yield, impact on livestock
	New crop pests and diseases	Decline in crop yield
Forest	Soil siltation	Loss of products like mushroom and thatch grasses
	Dry spells	Decreased in seasonal availability of products and enhanced forest fire
	Floods	Decrease in NTFPs like mushroom, wild vegetable and thatch grasses
	Wild fire	Loss of products
Human settlement and infrastructure	Floods	Houses and roads taken away
	Wind & hailstones	Roofs of houses taken away
Water sources and energy	Soil siltation	Loss of fresh water springs
	Dry spells	Loss/reduced water sources
Health	Soil siltation	Emergence of water borne and skin related diseases
	Dry spells	Outbreak of malaria & skin rashes
	Floods	Outbreak of malaria, water borne & skin related diseases
Cross cutting issues e.g. gender	Floods	Reduced mobility to children, elderly and women, disabled & affected disease victim
	Dry spells	Reduced access to water and increased burden to women, elderly, disabled & affected disease victim

Appendix 4: Continues……

Adaptive capacity

Parameter	Indicator(s) used	Criteria
Human assets	Demography	Children and youth population
	Education and literary	Secondary schools and awareness on climate change
	Skill labour	Employees in public and private sectors
	Acquired skills	Number of households participating in various trainings
Natural assets	Forest	Number of forest products in use at household level
	Water	Availability of safe drinking and irrigation water
	Land	Village ownership of land and productivity
	Rivers and dams	Number of rivers and dams available for various activities like fishing
Social assets	Social institutions	Community affiliation to formal and informal institutions
	Service provider and other organisation	Engagement of GOs, NGOs with community
Financial assets	Financial institutions	Number of cooperatives, saving/credit groups e.g. VICOBA, SACCOS
Physical assets	Infrastructure for services	Number of school available
		Access to communication infrastructure like roads, bridges, railway
		Availability of standard houses
		Cropping area under irrigation
		Access to health/medical services
		Access to clean water like community taps
	Information and communication	Access to mobile, radio, TV and newspapers
Food security	Cereal crop production	Area under cereal crops production per capita
	Animal protein	Animal protein consumption per capita

Appendix 5: **NTFPs identified and prioritised in Kilombero District**

Identified NTFPs	*Scores		
	Mpofu	**Njage**	**Miwangani**
Firewood	8(1)	9(1)	10(1)
Thatch grasses	7(2)	5	8(3)
Medicinal plants	6(3)	8(2)	4
Building poles	1	7(3)	3
Ropes	4	6	2
Wild vegetables	4	3	6
Withies	3	0	2
Mushroom	2	4	0
Fruits	1	1	0
Game meat	1	2	6
Weaving materials (*ukindu*)	0	0	9(2)
Honey	0	0	3

*Scores have been generated from pair-wise matrix from each village.
Number in parenthesis are the ranks from the pair-wise matrix indicating the three NTFPs of priority (1 = First, 2 =Second, 3 = Third)

Appendix 6: NTFPs resource assessment field form

Forest name:………………….……, Forest type:……..……..…, Recorder:…………..…..,
Date:…………………………….., Transect No………………., Plot No……………...….
GPS Readings: …..........……, (Eastings), ……..............................…(Northings)

Local name	Botanical name	DBH (cm)	Plant form	Uses	Part(s) used	No. of regenerants	Remarks