

**INSTITUTIONAL SYNERGIES TOWARDS MITIGATING CLIMATE CHANGE  
THROUGH DECENTRALIZATION OF FOREST RESOURCES: A CASE STUDY  
OF KAKAMEGA FOREST IN KENYA**

**Lawrence Njuguna Kanyiri (BSc. Env.Mgt)  
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## DECLARATION

### Declaration by candidate

I declare that this Thesis is my original work and has not been presented for a degree in any other university.

**Lawrence Njuguna Kanyiri**

**Department of Environmental Education**

Signature----- Date-----

### Declaration by supervisors

We confirm that this work reported in this thesis was carried out by this student under our supervision.

### Supervisors:

**Dr. James K.A. Koske**

**Department of Environmental Education**

**Kenyatta University**

Signature ----- Date-----

**Dr. Daniel G. Mang'uriu**

**Department of Environmental Education**

**Kenyatta University**

Signature ----- Date-----

## **DEDICATION**

I dedicate this piece of work to my parents Mr. Samuel Njuguna Kanyiri and Mrs. Joyce W. Njuguna, my beloved wife Lenna Wangari Njuguna and my daughter Lakeisha Waeni Njuguna.

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## DEFINITION OF TERMS

- Adaptation:** Actions and adjustments undertaken to maintain the capacity to deal with stresses induced as a result of current and future external changes
- Adaptive Capacity:** Preconditions that enable actions and adjustments in response to current and future external changes; dependent both on social and biophysical elements
- Climate change:** Significant and lasting change in the statistical distribution of weather patterns over period ranging from decades to millions of years. It may be a change in average weather conditions, or in the distribution of weather around the average conditions
- Ecological Sustainability:** This is a capacity of ecosystems to maintain their essential functions and processes, and retain their biodiversity in full measure for the benefit of future generations.
- Decentralization:** Downward redistribution of resources, responsibilities, and decision-making powers in a territorial and administrative hierarchy.
- Institutions:** Humanly created formal and informal mechanisms that shape social and individual expectations, interactions, and behavior.
- Mitigation:** Actions and policies that reduce exposure to climate change, for example, through regulation and institutional changes, technological shifts, alterations in behaviors, or change in location.
- Policy:** A plan or course of action, as of a government, political party, or business, intended to influence and determine decisions, actions and other matters.

## LIST OF ACRONYMS AND ABBREVIATIONS

CARD:	Community Action for Rural Development
CBO:	Community Based Organization
CDM:	Clean Development Mechanism
CFA:	Community Forest Association
EAWLS:	East African Wildlife Society
ENSO:	El Niño-Southern Oscillation
EO:	Environmental Officer
FAO:	Food Agricultural Organization
FD:	Forest Department
GDP:	Gross Domestic Product
GHGs:	Green House Gases
GPS:	Global Positioning System
ICIPE:	International Centre for Insect Physiology and Ecology
ICRAF:	International Center for Research in Agroforestry
IFRI:	International Forestry Research and Institutions
IPCC:	Intergovernmental Panel on Climate Change
ITCZ:	Inter-Tropical Convergence Zone.
KACOFA:	Kakamega Community Forest Association
KARI:	Kenya Agricultural Research Institute
KEEP:	Kakamega Environmental Education Programme
KEFRI:	Kenya Forestry Research Institute
KFS:	Kenya Forest Service
KFWG:	Kenya Forest Working Group
KWS:	Kenya Wildlife Service
MDGs:	Millennium Development Goals
Mha:	Millionhectares
MoA:	Ministry of Agriculture
MoCSS:	Ministry of Culture and Social Services
NCAR:	National Center for Atmospheric Research
NEMA:	National Environmental Management Authority
NEPAD:	New Partnership for Africa's Development
NRM:	Natural Resource Management

NTFPs: Timber and Non-Timber Forest Products  
ODA: Overseas Development Administration  
PPM: Parts Per Million  
SPSS: Statistical Package for Social Sciences  
UNFCCC: United Nations Framework Convention on Climate Change

## ABSTRACT

Climate change impacts have been exacerbated by extreme weather events among others and have led to disappearance of certain species of both food crops and trees. The adaptive capacity of the local community has mainly been on mitigation by basic methods that are mostly traditional in practice and knowledge. An investigation on how different institutions work together towards mitigating climate change through decentralization of forest resources was conducted among communities living adjacent to Kakamega forest; Kenya Forest Service, Kenya Wildlife Service, several Community Forest Associations among others. The study used descriptive design. The data collected (both institutional and biophysical) were used to address the research problem and meet the study objectives. The objectives were; to evaluate policies that were affecting adaptive outcomes in relation to adapting to climate change, to analyze roles played by KFS and KWS in mitigating climate change and to determine if decentralization of forest resources meets the goals of sustainability of Kakamega forest. Primary data were obtained from both Kakamega natural forest and Kakamega community forest Associations. Secondary data were collected and analyzed from all institutions that are responsible for the conservation and management of the forest. Stratified random sampling inside the forest arrived at the number of plots that were used for this study. They were used to determine the condition of the forest. The social economic and dependence on the forest by the communities adjacent to the forest was attained by cautiously guided interviews that ensured that all members were represented. The sample size was 50. The number of respondents interviewed was determined by KFS, KWS and a number of Community Forest Associations working around Kakamega Forest within a radius of five kilometers from the forest edge. There were no significant association on evaluating institutional policies that influence outcome in adapting to climate change (Chi-square=3.574; df=4;  $p \leq 0.05$  (0.467)). Chi square distribution reveal that there were no significant association on gender and policy legislation in Kakamega forest (Chi-square test=4.277; df=6;  $p=0.639$ ), rules that govern Kakamega forest to ensure decentralization (Chi-square test=1.416; df=4;  $p \leq 0.05$  (0.841), adaptation to climate change (Chi-square=9.135; df=8;  $p \leq 0.05$  (0.331), mitigation (Chi test = 0.683; DF = 1;  $p = 0.409$ ) and conflicts (Chi-square test= 1.895; df=2;  $p=0.388$ ). The study concluded that government and research institutions should enhance local community adaptation strategies to add value to diversification and communal pooling. Obstacles like social resistance, weak governance, inadequate information and ineffective institutional arrangements remains a challenge in mitigating climate change. The study recommended that Institutional coordination across scales, for better planning and implementation must be improved, use of proper crop management and also climate change adaptation and mitigation measures to be put in place. The study also gave suggestions that more research should be carried out on the same issues, new technologies to be added, institutions should be linked under one umbrella and further research done on introduction of new technologies to help community members benefit from forest products without depleting the forest.

## **CHAPTER ONE: INTRODUCTION**

### **1.1 Background Information**

Climate change and forests are intrinsically linked. Changes in global climate are already stressing forests through higher mean temperatures, altered precipitation patterns and more frequent and extreme weather events (FAO, 2006). At the same time, forests and the wood produce trap and store carbon dioxide, playing a major role in mitigating climate change. A forest is a complex ecosystem which is predominantly composed of trees and shrubs and is usually a closed canopy. Forests are storehouses of a large variety of life forms such as plants, mammals, birds, insects and reptiles. Forests have abundant microorganisms and fungi, which do the important work of decomposing dead organic matter thereby enriching the soil.

Nearly 4 billion hectares of forest cover the earth's surface, roughly 30 percent of its total land area. The forest ecosystem has two components- the non-living (abiotic) and the living (biotic) component. Climate and soil type are part of the non-living component and the living component includes plants, animals and other life forms. Plants include the trees and shrubs, climbers, grasses and herbs in the forest. Depending on the physical, geographical, climatic and ecological factors, there are different types of forests like evergreen forest (mainly composed of evergreen tree species i.e. species having leaves throughout the year) and deciduous forest (mainly composed of deciduous tree species i.e. species having leaf-fall during particular months of the year).

Each forest type forms a habitat for a specific community of animals that are adapted to live in it. The term forest implies 'natural vegetation' of the area, existing from thousands of years and supporting a variety of biodiversity, forming a complex ecosystem. Forests provide various natural services and products. Many forest products are used in day-to-day life, play important role in maintaining ecological balance, and contributes to economy (State of Environment Report – India, 2009).

Various institutions, for example, KFS and KWS are working to come up with strategies to adapt to climate change such as acquisition of additional forestland as a possible means to reduce greenhouse gas emissions via carbon sequestration. This is an important asset against global warming impacts and mitigating measures such as planting trees to sequester

carbon, and also actions that reduce the release of carbon into the atmosphere or that sequester the carbon that is already there will reduce the severity of changes in the future (King County Department of Natural Resources and Parks, 2008).

The process of devolved governance on common pool resources as a way to combating environmental challenges has been for long wanting (Blaher, 2006). Underlined by overlapping mandates and conflicting policies like Kenya Wildlife Service on management of wildlife and conservation, while Kenya Forest Service main interest is in plants and National Environmental Management Authority and Ministry of Agriculture dealing with general environment in Kenya, the local communities become victims of conflicting policies since different sector based extension officers rely on different issues on conservation matters.

Kakamega Forest is a tropical moist forest, rich in biodiversity and surrounded by densely populated areas as compared with forest in Bogor, Indonesia (Blaser, 2005), most of whom are dependent on the forest for their livelihoods and cultural rituals (Bergsdorf and Uster, 2006). It is located in Western Kenya and is 17,838 ha in size. The forest has a high population of approximately five hundred persons per square kilometer inside the forest.

Family farms range from 1 to 2 ha, and are owned by individual farmers. The major cash crops grown include tea, sugar cane and coffee, largely at small scale. Subsistence agriculture is practiced and involves growing maize, beans, pulses, bananas, sweet potatoes, millet, cassava and other root crops. Livestock are kept in very small numbers.

The Forest includes some of Africa's greatest hard and soft woods: Elgon teak, red and white stinkwoods and several varieties of Croton. The trees create the perfect environment for the birds, insects, butterflies and wildlife to flourish. Slowly, Kakamega forest has become famous around the world for being home to several hundred species of birds, snakes, lizards, insects, monkeys and other mammals (Bleher, 2006). A choice of walking trails and guided tours enable you to experience some of this fascinating, beautiful and unique forest first hand. Especially in the northern part of the forest, you will find virgin forest, intersected only by gurgling streams.

The forest represents a diversity of governance regimes, including longstanding collaborative forest management programs with forest adjacent communities. The

government agencies involved in management is Kenya Forest Service, Kenya Wildlife Service, Kenya Forestry Research Institute and Kenya Agricultural research Institute. The Kakamega Forest is very wet, with an average of 2008 millimeters of rain per year. Rainfall is heaviest in April and May ("long rains"), with a slightly drier June and a second peak roughly in August to September ("short rains"). January and February are the driest months. Temperature is constant throughout the year, with mean daily minimums of about 11<sup>0</sup> C and mean daily maximums of about 26<sup>0</sup> C. (Emerton, 1994).

Kenya's history of a highly centralized forest governance regime had a shift in policy in 2005 and law authorizing decentralization in the sector. However, Kakamega forest has been the focus of community collaborative management since the mid-1990s, in itself a form of decentralized management that seeks to directly involve communities and other local level actors in decision-making.

Institutional and social factors play a key role in shaping vulnerability through improvement of social services and infrastructure, poverty alleviation, community rights to access the important resources such as water and power: same climate phenomenon will have very different effects on the livelihoods of residents in the region, depending on the nature of institutional governance and local institutional arrangements. Some of the adaptive outcomes have been Communal pooling whereby KFS, through the Forest Act 2005, allows the community to form CFA's to conserve and manage the forest.

The CFA's form user groups of various interests within the forest, which in this case means forest zonation. This is one way of communal pooling of resources sustainably. Diversification as another adaptive outcome whereby KFS has been introducing new technologies for forest plantations, on farm tree planting, dry lands species introduction from the edge of the forest, Aloe Vera marketing and packaging among others. Through exchange, KFS enable improved market access for the locals for example improvement of access roads, banking, health facilities etc. Information dissemination will be through open days and radio broadcasts. KFS through storage will introduce Clean Development Mechanisms and payment for environmental services (Niamir, 1995).

The main source of income for most members of the community revolves around formal employment and remittances, agricultural and livestock production, forest based activities and some small-scale business enterprises. Fuel wood, grazing, poles and thatch grasses

were prioritized over other uses such as medicinal plants, charcoal, ropes and honey. They were found to be the important products for the communities (Blaser, 2005). Forest products were mainly sold in nearby urban areas of Kakamega and Kisumu.

## **1.2 Statement of the Problem**

Like most parts of Kenya, communities around Kakamega forest are uncertain about future access to the forest resource. National policies on forest use have been changing with the coming of the new constitution that says in Chapter 5 article 69 that, “every person has a duty to cooperate with State organs and other persons to protect and conserve the environment and ensure ecologically sustainable development and use of natural resources” (G.O.K, 2008).

This should ensure sustainable exploitation, utilization, management and conservation of the environment and natural resources, and ensures equitable sharing of the accruing benefits by the communities living in and adjacent to the forest.

The International Forestry Research Institute rates Kakamega forest as one of the high value, owing to its high presence of commercial plant species, but also shows that regeneration of these species is poor. Recent studies indicate a high level of human impact throughout the forest with illegal logging being most widespread and significantly lower at sites managed by the Kenya Wildlife Service than in the Kenya Forest Service sites.

Institutional and social factors play a key role in shaping vulnerability: the same climate phenomenon will have very different effects on the livelihoods of residents in the region, depending on the nature of local governance and local institutional arrangements (Agrawal, 1999). In Kakamega forest, strong institutional norms around labour sharing are needed to reduce the ability of households to adapt by migrating or diversifying. Social groups that do not have secure rights to land will find it more difficult to diversify asset portfolios or engage in exchange. Resources are not decentralised in a good manner that will ensure all community members have equal share of the resource use and consumption. Closely knit social networks will make it easier to undertake communal pooling of resources.

Climate change impacts have been exacerbated by prolonged drought since it is the problem of disappearance of certain species of both food crops and trees. The adaptive capacity of the local community has mainly been on mitigation by basic methods that are mostly traditional practices and knowledge. Over 50% of the forest cover has been lost in the last

two decades to agricultural farms due to increased population across the county. Kakamega forest has about 380 species of plants, and over 350 species of birds (Kifcon 1994).

Although much has been documented on diverse projects both by Government and International organizations aimed at environmental conservation of the forest, there is little information concerning institutional synergies towards climate change mitigation and adaptation. Despite the similarities in ecology, prominence of both forests in local and national economies, including conservation of biological diversity, there were some sharp differences in the institutional regimes as concerns their management regime.

### **1.3 Research Questions**

The study was guided by the following research questions:

- i. What institutional policies influence outcomes in adapting to climate change in Kakamega County?
- ii. What roles do Kenya Forestry Service and Kenya Wildlife Service play in mitigating climate change in Kakamega County?
- iii. To what extent does decentralization of forest resources meet the goals of sustainability in Kakamega County?

### **1.4 Hypotheses**

- i.  $H_0$ : There are no institutional policies that influence outcomes in adapting to climate change.
- ii.  $H_0$ : KFS and KWS have no role in mitigation actions to climate change.
- iii.  $H_0$ : Decentralization of forest resources does not meet the goals of sustainability at Kakamega forest.

### **1.5 Broad Objective**

The main objective of this study was to assess what different institutions were doing in curbing climate change effects through decentralization of management of forest. The study attempted to identify institutional and socio-economic characteristics and management practices, which may influence adaptation measures towards climate change.

### **1.6 Objectives**

The study is set:-

- i. To evaluate the institutional policies that influence outcomes in adapting to climate change.

- ii. To analyze the roles played by Kenya Forest Service and Kenya Wildlife Service in mitigating climate change.
- iii. To determine if decentralization of management of forest resources meets the goals of sustainability of Kakamega forest.

### **1.7 Significance**

Decentralization of the forest resources has set milestones in meeting the goals of sustainability and climate change in environments characterized by conflicting policies. The study is vital especially to various institutions like Kenya Wildlife Service, Kenya Forest Service, research institutions such as Kenya Forestry Research Institute and policy makers because it will help them to come up with comprehensive guidelines of policy interaction on how forest protection and climate change ought to interplay.

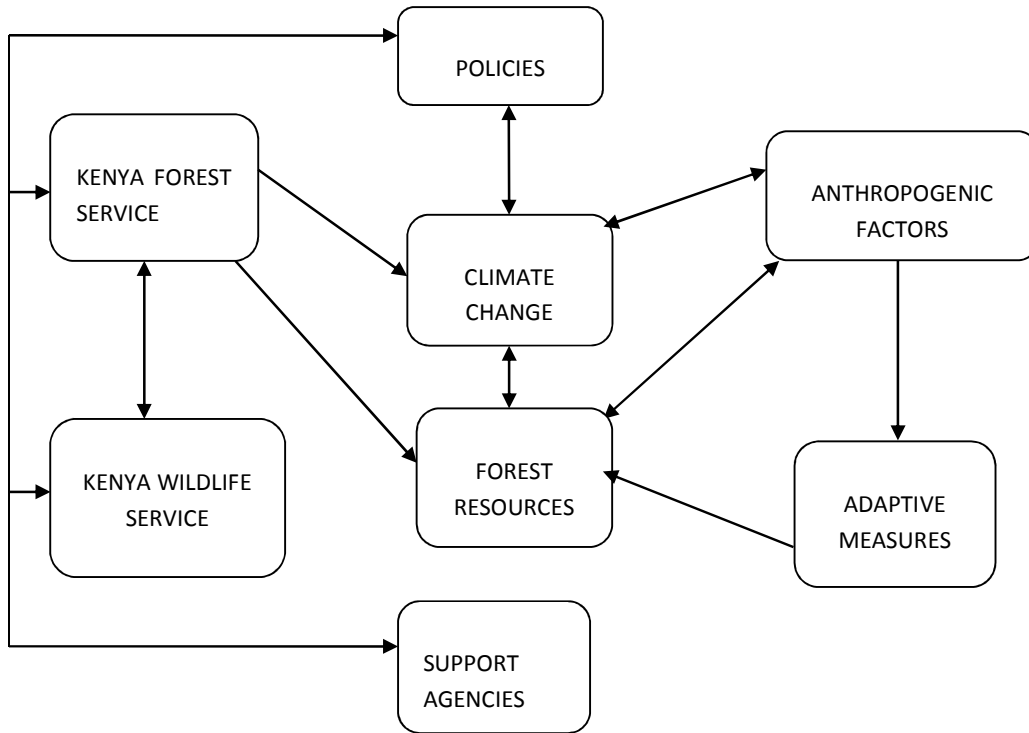
The research study would also help other researchers and students who wish to conduct further research in line with risks and opportunities in climate change. The research would inform people living within and around the forest to appreciate the importance and benefits of forests in mitigating climate change.

### **1.8 Conceptual Framework**

Climate change has affected forest resources in various ways. The study investigated the relationship between KWS and KFS, the support agencies and the local stakeholders on how they influence policy evaluation from the KWS and KFS, and how these affected the forest resources and the adaptive measures of the communities around Kakamega forest.

Figure 1.1 below shows that Climate Change is being influenced by anthropogenic factors including poor methods of farming, charcoal burning, and exhaust fumes and industrialization from automobiles. These also affect the forest resources through cutting of trees, cultivating along and inside the forest. Adaptive measures and Climate Change influence each other through reducing vulnerability to climate change. This involves preventing and tolerating the loss of resources.

Kenya Forest Service and Kenya Wildlife service influence each other and climate change through their policies on adaptation and mitigation to climate change through the use of forest and wildlife resources.



**Figure 1.1:** Interrelationships between climate change, policies, forest resources, institutions and adaptive measures

Policies influence through improvement and protection of resources through putting proper policies in place to mitigate climate change. Support agencies include local institutions that work together to mitigate climate change

## **CHAPTER TWO: LITERATURE REVIEW**

### **2.1 Introduction**

This chapter reviews the relevant literature of how Kenya Forestry Service and Kenya Wildlife Service were working together towards mitigating climate change through decentralization of forest resources. It also reviews if decentralization of forest resources was meeting the goals of sustainability and climate change in an environment characterized by conflicting policies and what the various institutions were doing to address climate change in Kenya.

### **2.2 Global Status of Forests**

Global forests and woodlands can be classified into nine general categories namely; tropical rain forests, tropical moist forests, tropical dry forests, tropical shrubs, tropical mountain forest, subtropical humid forests, subtropical dry forests, subtropical mountain forests and plantations. Mangrove forests cover 3,390,107 ha (FAO, 2003a). Only 32.5 million ha of global forests and woodlands, or 5 per cent of the total forest area, are formally protected (FAO, 2003b). The forest sector in Africa plays an important role in the livelihoods of many communities and in the economic development of many countries. This is particularly so in Western, Central and Eastern Africa where there is considerable forest cover. Africa has a high per capita forest cover of 0.8 ha per person compared to 0.6 ha globally (FAO, 2002).

Deforestation and forest degradation, however, are impairing the capacity of forests to contribute to food security and other needs. This article focuses on tropical forests, which are currently experiencing the highest rates of clearing and degradation. From 1980 to 1990, an estimated 146 million ha of natural forests in the tropics were cleared, with an additional loss of 65 million ha between 1990 and 1995 (FAO, 1997). The area of degraded forest (defined below) is estimated to be even greater (WRI, 1994).

Tropical forests are located in areas of the world with the highest concentration of the food insecurity. They are home to approximately 300 million people who depend on shifting cultivation, hunting and gathering to survive (FAO, 1996a); many are at risk of not consuming enough food to meet their daily energy requirement on a chronic, transitory or seasonal basis. In addition to these forest inhabitants, millions of people living adjacent to forest areas depend on forests for some aspect of their food security.

The full implication of the loss or deterioration of tropical forests for humankind as well as other life forms is not known, what is known, however, is that the loss of forest resources can lead to diminished income- and food-generating capacity for forest-dependent communities, higher rates of soil erosion and siltation of waterways, loss of species and genetic diversity and an increase in carbon emissions which contribute to global warming (Kaimowitz, *et al*,1998).

It is important to recognize that in addition to these losses, deforestation and forest degradation may also generate profits, from timber or other product sales, forest food products for consumption or crop and livestock production for subsistence or the market. In assessing the implications of forest degradation, it is important to consider how the value obtained compares with the costs incurred, taking into account the full implications for the global community, including non-human life forms.

Moreover, forest degradation represents a transfer of value among different groups. Thus, it is necessary to identify how the transfer affects different groups with different risk of food insecurity. With this knowledge, better informed choices can be made of trade-offs involved in forest management. For the people who live in or near the forest, an obvious impact could be a decrease in biomass produced that is a decrease in the future capacity of the forest to produce wood, fodder, fruit, medicinal plants and so on.

### **2.3 Forests Status in Africa**

It is roughly one-fifth of Africa, or about 6.3 million kilometers covered by forests. This masks huge variation in the type and significance of forest cover. This information could include everything from very small patches of scrubland or planted woodlot although not trees used in agro forestry though to the large contiguous areas of closed canopy high forests found in the equatorial belt (FAO, 2006). The FAO global forest assessment recognizes three broad regions of forests in Africa: Northern; West and Central; and Eastern and Southern. These represent areas with similar environmental and social economic conditions, although there is still significant variation between them (FAO, 2006).

### **2.4 The Economic Role of Forest in Africa**

On average, forests account for 6 per cent of Gross Domestic Product (GDP) in Africa, which is the highest in the world (NEPAD, 2003). In Uganda, for example, forests and

woodlands are now recognized as an important component of the nation's stock of economic assets and they contribute in excess of US\$546.6 million to the economy through forestry, tourism, agriculture and energy (Emerton and Muramira, 1999). Forests and woodlands also contribute to the long-term social and economic development goals of NEPAD and can play an important role in addressing the Millennium Development Goals (MDGs) and meeting its targets. They provide energy, food, timber and non-timber forest products (NTFPs) and are important contributors to wealth and health at the household, community, national, sub-regional, regional and even global level.

Forests and woodlands are key components of the environment and provide essential services that are critical to combating land degradation and climate change, as well as to conserving wetlands, coastal areas and freshwater systems (Bergsdorf and Uster, 2006). Forests and the benefits provide in the form of food, income and watershed protection have an important and often critical role in enabling people around the world to secure a stable and adequate food supply. Forests are important to food security because they are one of the most accessible productive resources available to them.

## **2.5 Anthropogenic Impacts Contributing to Climate Change in Kenya**

Major impacts contributing to climate change in Kenya include over utilization and degradation of natural resources; reduction in tree cover on farmlands, soil erosion and deforestation; industrialization and rapid urbanization. Expounding, the impacts on the deforestation and wetland degradation were addressed since their conservation and management acts as major opportunities for carbon sinks.

### **2.5.1 Over-Utilization and Degradation of Natural Resources**

Forest products, including food and household items, and the income generated by them can be quite significant to the food security of local communities throughout the developing world, many of which are food insecure (Reddy and Chakravarty, 1999; Arnold and Townson, 1998; Townson, 1995; Hoskins, 1990; FAO, 1989; FAO, 1990). The poorest households generally have the highest degree of reliance on forest products for income and food, as they have the least access to cultivatable land and so supplement their production with the gathering of forest products on common-property forest lands (lands that are owned and managed collectively) or open-access forest lands (lands that have no effective

collective or private ownership status) (Reddy and Chakravarty, 1999; Jodha, 1990). The latter category is more vulnerable to overexploitation.

In addition, forest products also have an important role in food security as "buffer" foods, helping to meet dietary needs during periodic food shortages (Arnold and Townson, 1998; FAO, 1990). Even if forest products only constitute a small part of overall food consumption and income generation, their absence at a critical time can greatly increase the risk of food shortages. This loss of "consumption insurance" for food-insecure households can have further negative impacts through its effect on agricultural and natural resource investment strategies. Evidence has indicated that the risk of food insecurity results in low-risk and low-return investment patterns (Holden and Binswanger, 1998).

Forest degradation also influences food security through its impact on supplies of fuel wood, which is a major source of income to many poor households (Townson, 1995). Two in five people worldwide, or approximately 3000 million people, rely on fuel wood or charcoal for heating or cooking, and approximately 100 million people are already facing a "fuel wood famine" (FAO, 1995). A decreased fuel supply creates constraints on food preparation that can lower nutritional values and increase risk of food-borne diseases (FAO, 1989). In many parts of the world, women are responsible for collecting fuel wood, and the increased time required for collection of scarcer resources can impede women's ability to participate in household and agricultural labour and thus jeopardize the household's food security (FAO, 1987).

In addition to biomass, other benefits of forests to on-site users include regulation of soil and water flows as well as shade and windbreak protection. Forest degradation that involves the loss of ground cover exposes soil to rainfall and can result in increased erosion (Bruijnzeel, 1990; Chomitz and Kumari, 1996). The loss of nutrient-rich topsoil can result in significant decreases in agricultural productivity (Tengberg, Stocking and Dechen, 1998).

#### ***2.5.1.1 Local watershed impacts of forest degradation***

Loss of ground cover in local watersheds can result in increased erosion leading to sedimentation of waterways that may have a negative impact on downstream irrigation, fishery and dam operations. In some cases these impacts can be quite high, although they may occur only after a long time lag (Chomitz and Kumari, 1996; Hodgson and Dixon,

1988). Forest degradation can result in increased runoff and thus increased flooding potential within local watersheds. Changes in the water table may occur as well, although the processes can affect the water table in opposite ways: reduced vegetative cover can lead to reduced water loss from evapo-transpiration, while runoff is likely to increase, although it may or may not percolate into groundwater tables (Chomitz and Kumari, 1996).

#### ***2.5.1.2 Impacts of forest degradation***

Two important services provided by forest ecosystems that benefit the global community are carbon sequestration, storage, and the conservation of biological diversity through the provision of habitat for highly diverse plant and animal species.

Global climate change is associated with rising levels of greenhouse gases (in particular carbon dioxide) in the atmosphere. Forest ecosystems, including above- and below-ground components, are major carbon sinks, taking up carbon from the atmosphere; thus, they have an important role in mitigating climate change. The potential impacts of climate change are as yet poorly understood, but climate variability and increasing temperatures are likely to have a more severe effect on food security in the poorest areas of the world (FAO,2000). However, adjustment costs in response to changes brought about by global warming could be significant world-wide (Zilberman and Sunding, 1999).

Forests are the most species-diverse terrestrial habitat on a global level. Tropical moist forests are home to between 50 and 90 percent of the world's terrestrial species (WRI, 1999; FAO, 1999). The genetic resources of the forest provide the raw material for improvement of food and cash crops, livestock and medicinal products. Genetic diversity in crop and livestock species may have positive benefits to producers, particularly in marginal production zones as insurance against production risks (Brush and Meng, 1998). Moreover, the conservation of genetic resources may prove to have significant future benefits that are currently unknown, e.g. in new medical treatments or resistance to future disease threats. The most frequently cited cause of genetic erosion is the destruction or degradation of forest and bush lands (FAO, 1996b). Much of this loss is irreversible, such as the extinction of species.

### ***2.5.1.3 Poverty and forest degradation***

Because forests are often located in remote areas, are under some form of collective or State ownership and are difficult to monitor, they are relatively accessible to groups that lack assets and are consequently food insecure. Incursions or settlements on forestlands may be the only means for smallholders or the landless, many of whom are food insecure, to gain access to land for agriculture. For the same reasons, forest communities that traditionally depend on forest resources for their food security are vulnerable to incursions or expropriation from outside interests. In addition, many of the products and services of the forest can be transformed into food or income without the need for a large capital investment; production can be obtained from forests at relatively low cost. However, as has been mentioned above, populations that are dependent on the forest for food security are sometimes themselves agents of forest degradation. What drives the food insecure to compromise their future production capacity?

First, a combination of outside "conditioning" factors narrows the population's opportunities for achieving a sustainable livelihood (Vosti and Reardon, 1997). Two of the most important conditioning factors are the degree of population pressure on both agricultural and forestlands and the productivity of land under production. These in turn are driven by population growth rates, migration and land utilization patterns (as well as soil type, topography, rainfall, climate, etc.). Increased population pressure on land resources can result in pressure for more extensive agricultural production on new (for example forest) lands, or more intensive use of existing production resources, including forests (WRI, 1999). Decreases in the availability of forestlands for food security-related production because of logging, migration settlements or the creation of forest reserves can also result in increased pressure on remaining forestlands.

Government policies sometimes exacerbate these pressures. For example, pricing or taxation policies may reduce the profitability of intensifying production on existing agricultural lands or may enhance the profitability of forest intrusions (Heath and Binswanger, 1998; Hecht and Cockburn, 1998). Policies for privatization of lands that are either openly accessible to the poor or managed under traditional communal property rights schemes can limit options available to the food insecure (Ascher, 1995; Das Gupta, 1996). Such measures can lead to forest degradation by putting pressure on food-insecure groups

(both traditional forest users and groups driven to forest areas from other locations in search of food security) to intensify forest use or increase use of forest resources.

Second, poverty-specific factors such as lack of power and lack of assets reduce the population's capacity to respond to existing opportunities or new circumstances (Vosti and Reardon, 1997). Generally, the food insecure are among the least empowered groups in society, so their ability to influence policies to reflect their needs is limited. Lack of assets, whether in the form of production or financial resources or human capital (i.e. technological capacity, which could include both modern and traditional technologies as well as health status) can influence how the food insecure manage their limited resources. Pressure to derive the greatest possible value from their resources in the present can prevent them from making investments that could generate future wealth. Given the limited options available to them, managing the forest in a way that can have a negative impact on their own future food security, it may be the only alternative available.

### **2.5.2 Deforestation**

Deforestation is the clearing of naturally occurring forests and bushes from forested area by cutting and /or burning of trees. There are several reasons why deforestation occurs: trees or derived charcoal can be sold as commodities and used by humans, while cleared land is used as pasture, farming, plantations of commodities and human settlement. The removal of trees without sufficient reforestation has resulted in damage to habitats, biodiversity loss, aridity, soil erosion, and climate change.

Deforested regions typically incur significant adverse soil erosion and frequently degrade into wasteland. Moreover, these disregard or ignorance of intrinsic value, lack of ascribed value, careless forest management and incomplete environmental law are some of the factors that allow deforestation to occur on a large scale. There are many root causes of deforestation, including corruption of government institutions (Burgonio, 2008; WRM, 2003), the inequitable distribution of wealth and power, population growth (Alain, 2000) overpopulation (Butler, 2009) and urbanization. Globalization is often viewed as another root cause of deforestation, though there are cases in which the impacts of globalization (new flows of labor, capital, commodities, and ideas) have promoted localized forest recovery.

In many countries, deforestation is an ongoing issue that is causing extinction, changes to climatic conditions, desertification, and displacement of homegrown people. In 2000 the United Nations Food and Agriculture Organization (FAO, 2000) found that the role of population dynamics in a local setting may vary from decisive to negligible and that deforestation can result from a combination of population pressure and stagnating economic, social and technological conditions (Alain, 2000). Moreover, it facilitates the rate of drought occurrences, limits poverty reduction goals, and leads to low living standard of people and can be a cause for political instability of a country. Among countries with a per capita gross domestic product (GDP) of at least \$4,600, net deforestation rates have ceased to increase (The New York Times, 2009).

Many important forest functions have no markets, and hence, no economic value that is readily apparent to the forest owners or the communities that rely on forests for their well-being. From the perspective of the developing world, the benefits of forests as carbon sinks or biodiversity reserves go primarily to richer developed nations and there is insufficient compensation for these services. Developing countries feel that, the poor should not have to bear the cost of preservation when the rich created the problem (Erwin, *et al.*, 2000).

Damage to forests and other aspects of nature could halve living standards for the world's poor and reduce global GDP by about 7% by 2050, a major report concluded at the Convention on Biological Diversity (CBD) meeting in Bonn. Historically, utilization of forest products, including timber and fuel wood, have played a key role in human societies, comparable to the roles of water and cultivable land. Today, developed countries continue to utilize timber for building houses, and wood pulp for paper. In developing countries almost three billion people rely on wood for heating and cooking (<http://atlas.aaas.org/pdf/63-66.pdf>).

Reducing emissions from the tropical deforestation and forest degradation in developing countries has emerged as a new potential area to complement ongoing climate policies. The idea consists in providing financial compensations for the reduction of greenhouse gas emissions from deforestation and forest degradation.

Deforestation is a contributor to global climate change (Philip and Laurance, 2004), and is often cited as one of the major causes of the enhanced greenhouse effect. Tropical deforestation is responsible for approximately 20% of world greenhouse gas emissions

(Philip and Laurance, 2004). According to the Intergovernmental Panel on Climate Change (IPCC) deforestation, mainly in tropical areas, account for up to one-third of total anthropogenic carbon dioxide emissions. Trees and other plants remove carbon (in the form of carbon dioxide) from the atmosphere during the process of photosynthesis and release oxygen back into the atmosphere during normal respiration. Actively growing trees or forests can remove carbon over an annual or longer time frame. Both the decay and burning of wood release much of this stored carbon back to the atmosphere. In order for forests to take up carbon, the wood must be harvested and turned into long-lived products and trees must be re-planted (Prentice, 1999). Deforestation may cause carbon stores held in soil to be released.

Forests are stores of carbon and can be either sinks or sources depending upon environmental circumstances. Plants use carbon dioxide during photosynthesis to make sugars, which may either be consumed in respiration or used as the raw material to produce other organic compounds needed for plant growth and development. It is produced during respiration by plants, and by animals, fungi and micro-organisms that depend either directly or indirectly on plants for food. It is thus a major component of the carbon cycle. Carbon dioxide is generated as a by-product of the combustion of fossil fuels or the burning of vegetable matter, among other chemical processes. Small amounts of carbon dioxide are emitted from volcanoes and other geothermal processes such as hot springs and geysers, and by the dissolution of carbonates in crystal rocks.

Emissions of carbon dioxide by human activities are currently more than 130 times greater than the quantity emitted by volcanoes, amounting to about 27 billion tons per year (VGTE, 2007). Up to 40% of the gas emitted by some volcanoes during sub-aerial volcanic eruptions is carbon dioxide (Sigurdsson and Houghton, 2000). It is estimated that volcanoes release about 130-230 million tons of carbon dioxide into the atmosphere each year. This is about a factor of 1000 smaller than the sum of the other natural sources and factor of about 100 smaller than the sources from human activity. However, the incineration and burning of forest plants in order to clear land releases tones of carbon dioxide, which contributes to global warming (Philip and Laurance, 2004).

In 1850, atmospheric carbon dioxide was about 280 ppm, and today it is about 385 ppm (Tans, 2008). As of March 2009, carbon dioxide in the earth's atmosphere was at a concentration of 387 ppm by volume. Atmospheric concentrations of carbon dioxide

fluctuate slightly with the change of the seasons, driven primarily by seasonal plant growth in the Northern Hemisphere. Concentrations of carbon dioxide fall during the northern spring and summer as plants consume the gas, and rise during the northern autumn and winter as plants go dormant, die and decay (Tans, 2008). Carbon dioxide is a greenhouse gas. It transmits visible light but absorbs strongly in the infrared and near-infrared.

Human activities such as the combustion of fossil fuels and deforestation have caused the atmospheric concentration of carbon dioxide to increase by about 35% since the beginning of the age of industrialization. Yearly average increase of atmospheric carbon dioxide in the 1960s was 37% of the 2000-2007 in average (Tans, 2008). Carbon exists in the earth's atmosphere primarily as gas. Although it is a small percentage of the atmosphere (approximately 0.04% on a molar basis, and increasing), it plays an important role in supporting life. However, for short-term (under ten minutes) exposure, the United States National Institute for Occupational Safety and Health (NIOSH, 2003) and American Conference of Government Industrial Hygienists (ACGIH) limit is 30,000 ppm (3%). NIOSH also states that carbon dioxide concentrations exceeding 4% are immediately dangerous to life and health (NIOSH, 2003).

Other gases containing carbon in the atmosphere are methane and chlorofluorocarbons (the latter is entirely anthropogenic). The overall atmospheric concentration of these greenhouse gases has been increasing in recent decades. Trees convert carbon dioxide into carbohydrates during photosynthesis, releasing oxygen in the process. This process is most prolific in relatively new forests where tree growth is still rapid. The effect is strongest in deciduous forests. This is visible as an annual signal in the keeling curve of measured carbon dioxide concentration. Northern hemisphere spring predominates, as there is far more land in temperate latitudes in that hemisphere than in the southern. A number of processes influence carbon storage in the biosphere on different time-scales: while net primary productivity follows a diurnal and seasonal cycle, carbon can be stored up to several hundreds of years in trees and up to thousands of years in soils. Changes in those long-term carbon pools may thus affect global climate change. Forests store 86% of the planet's aboveground carbon and 73% of the planet's soil carbon (Sedjo, 1993).

A change in the type, distribution and coverage of vegetation may occur given a change in the climate; this much is obvious. In any given scenario, a mild change in climate may result in increased precipitation and warmth, resulting in improved plant growth and the

subsequent sequestration of airborne carbon dioxide. Larger, faster or more radical changes, however, may well result in vegetation stress, rapid plant loss and desertification in certain circumstances (Bachelet *et al.*, 2001).

Land use and land management practices have a major impact on natural resources including water, soil, nutrients, plants and animals. Land use information can be used to develop solutions for natural resource management issues such as salinity, ecosystem balance and water quality. For instance, water bodies in a region that has been deforested or having erosion will have different water quality than those in areas that are forested. Increased carbon dioxide in the atmosphere has led to decreasing alkalinity of seawater and there is some concern that this may adversely affect organisms living in the water. In particular, with decreasing alkalinity, the availability of carbonates for forming shells decreases (Garrison, 2004).

The water cycle is also affected by deforestation. Trees extract groundwater through their roots and release it into the atmosphere. When part of a forest is removed, the trees no longer evaporate away this water, resulting in a much drier climate. Deforestation reduces the content of water in the soil and groundwater as well as atmospheric moisture. Deforestation reduces soil cohesion, leading to erosion, flooding and landslides. As a result, the presence or absence of trees can change the quantity of water on the surface, in the soil or groundwater, or in the atmosphere. This in turn changes erosion rates and the availability of water for either ecosystem functions or human services. Tropical rainforests produce about 30% of our planet's fresh water (Field, 2006).

Deforested areas become sources of surface water runoff, which moves much faster than subsurface flows. That quicker transport of surface water can translate into flash flooding and more localized floods than would occur with the forest cover. Deforestation also contributes to decreased evapotranspiration, which lessens atmospheric moisture that in some cases affects precipitation levels downwind from the deforested area. Deforestation generally increases rates of soil erosion, by increasing the amount of runoff and reducing the protection of the soil from tree litter.

Tree roots bind soil together, and if the soil is sufficiently shallow, they act to keep the soil in place by also binding with underlying bedrock. Tree removal on steep slopes with shallow soil increases the risk of landslides, which can threaten people living nearby.

However most deforestation only affects the trunks of trees, allowing the roots to stay rooted, negating the landslide for short run. Anthropogenic factors are human activities that change the environment. In some cases, the chain of causality of human influence on the climate is direct and unambiguous (for example, the effects of irrigation on local humidity) whilst in other instances it is less clear. Various hypotheses for human-induced climate change have been argued for many years. Presently, the scientific consensus on climate change is that human activity is very likely the cause for the rapid increase in global average temperatures over the past several decades (IPCC, 2007).

Consequently, the debate has largely shifted onto ways to reduce further human impact and to find ways to adapt to change that has already occurred. Of most concern in these anthropogenic factors is the increase in carbon dioxide levels due to emissions from fossil fuel combustion, followed by aerosols and cement manufacture. Other factors, including land use, ozone depletion, animal agriculture (Steinfeld *et al.*, 2006) and deforestation, are also of concern in the roles they play - both separately and in conjunction with other factors - in affecting climate. A key factor in controlling deforestation could come from the Kyoto Protocol.

Reducing Emission from Deforestation and Forest Degradation (REDD) mechanisms, which provide financial incentives for avoided deforestation, could be implemented in a future Kyoto Protocol (Walsh, 2008). At the moment, REDD is not implemented in any of the flexible mechanisms defined under the Kyoto Protocol (Clean Development Mechanism, Joint Implementation and Emission Trading). Path diagrams represent many structural equation models, with which researchers describe their theories about the relationships among observed and unobserved variables. The path diagram representation of complicated structural relationships is much more than a description of a few predictors and outcomes blocked. This means that we cannot simply use multiple regression techniques to analyze such structural models (Yung, 2008). The technique of analyzing the path is not only intuitive but also facilitates a good understanding of the relation of various parts of the model and provides a clear picture of reactions of parameters to a misspecification.

Confirmatory and Exploratory Factor Analysis are powerful statistical techniques of structural equations modeling (Suhr, 2000). CFA allows the researcher to test the hypothesis that a relationship between the observed variables and their underlying latent construct(s) exists. The researcher uses knowledge of the theory, empirical research, or both, postulates

the relationship pattern a priori and then tests the hypothesis statistically. The techniques have similarities and differences. Determine the type of analysis a priori to answer research questions and maximize our knowledge. SEM, and covariance structural analysis in particular, has been widely used in the medical, social and behavior sciences. Due to the effort of many methodologists, the capacity of SEM in modeling more complex data structures is increasing (Yuan *et al.*, 2008). When simultaneously modeling the relation among manifest and latent variables as well as measurement errors, misspecification is inevitable.

## **2.6 Impacts of Climate Change in Kenya**

Africa is one of the most vulnerable continents to climate change - a situation aggravated by the interaction of multiple stresses occurring at various levels and as a result of its low adaptive capacity (IPCC, 2007). Kenya is already experiencing the impacts of climate change and more are anticipated to occur with increased warming of temperatures. Direct impacts include changes in weather patterns with decreasing rainfall, increased temperatures and higher evaporation rates in the dry areas. Under conservative warming estimates, rainfall is expected to increase by 5 to 20 percent during the months of December to March while a decrease of between 5 to 10 percent will occur in June to August (Meteorological Department, 2010). Under more rapid warming scenarios, Kenya and other East African countries may receive up to double precipitation while arid areas are likely to receive even less than at present (IPCC, 2001).

### **2.6.1 Socio - Developmental Strategies**

Indirect impacts of climate change concern socio - developmental strategies such as health, livelihood support, education and conflict. Frequent drought spells over the years have led to severe water shortage, increased risk of food shortage and expansion of aridity and desertification into marginal lands and changes in the planting dates of annual crops (FAO, 2003a). There will be notable increase of fungal outbreaks and insect manifestations due to changes in temperature and humidity along with reduction in ecosystem integrity, its resilience and decline in biodiversity (Emerton and Muramira, 1999).

Other impacts include increase in human, crop and animal vector-borne diseases such as malaria, cholera and Rift Valley Fever; sea level rise resulting to inundation of low-lying areas along the coast and islands while increase in ocean acidity will result in coral reef

bleaching along the Kenyan Coast. Melting of glaciers on Mount Kenya is already occurring while extreme weather events will increase (Githeko, *et al.*, 2000). Loss of biodiversity, spread of disease margins and inundation of low-lying coastal areas will severely affect the tourism sector that is Kenya's second foreign exchange earner.

### **2.6.2 Biodiversity and Climate Change**

Biological diversity is essential to maintaining ecosystem processes and services. Climate change poses a significant threat to biological diversity (Parmesan and Yohe, 2003). Before climate change became a credible threat, biological diversity was considered at risk at regional to global scales in response to many human stressors such as land use. Losses of biological diversity over the past 100 years are historically unprecedented, thus climate change represents an additional source of stress on an already at-risk pillar of ecosystem sustainability.

Temperature and precipitation are predicted to change, and many questions exist about the challenges that these climate changes may pose to biological diversity. Research has shown that climate change poses an even greater threat to biological diversity than land use (Sala *et al.*, 2000; Thomas *et al.*, 2004). Species respond to environmental change based on their habitat needs, competitive abilities, and physiological tolerances. Although increases in richness are predicted for some areas (cool areas that are predicted to warm) (Curie, 2001), overall biological diversity is expected to decline precipitously. Cumulative effects of climate change and land use are difficult to assess.

The most significant effects of climate change on biological diversity are expected to be in response to increases in summer temperatures in temperate countries (Currie, 2001). Theoretically, ecological communities could move up in elevation and latitude (Walther *et al.*, 2002); however, successful migrations will depend on the rate of climate change relative to essential habitat needs and key community interactions. More likely is that existing communities will become decoupled, with some species able to track favorable climate envelopes, while others will lag behind (Midgley *et al.*, 2002).

Species most at risk of climate change are those with small geographic ranges (e.g., local endemics), narrow physiological tolerances, limited dispersal abilities, habitat associations, strong interspecific dependencies, low genetic diversity, and those that have recently experienced population declines (Midgley *et al.*, 2002). The likely result will be the

extinction of many species, reduced biological diversity, and changes in the composition of remaining communities. Temperature changes alone are expected to result in the extinction of a minimum of 18 to 24 percent of all species by 2050 (Thomas *et al.*, 2004).

Communities are expected to reflect species able to profit by altered climatic conditions, the invisibility of original communities, and the energetic limits imposed by climatic conditions (Currie, 2001). Mediterranean and grassland ecosystems are expected to be particularly vulnerable to invasion because of their moderate diversity and relative ecological isolation, whereas northern temperate forests have relatively low vulnerability (Sala *et al.*, 2000). Reductions in biological diversity in existing communities are likely to diminish the ecosystem services and resilience of those communities to environmental stressors by reducing their functional redundancy (Kremen, 2005; Loreau *et al.*, 2001; Reich *et al.*, 2004).

Major uncertainties remain regarding the fate of biological diversity and what options exist for adaptation and mitigation (Thomas *et al.*, 2004). Species extinctions are expected to lag behind climate changes, particularly in longer lived species. The composite effects of climate change and land use are unknown, and at worst could be multiplicative. It is also difficult to predict the competitive and adaptive abilities of species in areas with no current ecological analog. Finally, effects on the genetic diversity and adaptability of species are likely to be significant (Hampe and Petit, 2005) but largely are unknown (Parmesan and Yohe, 2003).

Biodiversity is an important resource for African people. Uses are consumptive (food, fiber, fuel, shelter, medicine, wildlife and trade) and non-consumptive (ecosystem services and the economically important tourism industry). Given the heavy dependence on natural resources in Africa, many communities are vulnerable to the biodiversity loss that could result from climate change. The impact of climate change on humans will also be compounded by climate change-induced alterations of agriculture, water supply and disease. Most of Africa relies on rain-fed agriculture.

As a result, it is highly vulnerable to changes in climate variability, seasonal shifts, and precipitation patterns. Any amount of warming will result in increased water stress. Roughly, 70 percent of the population lives by farming and 40 percent of all exports are agricultural products (WRI, 1996). One-third of the income in Africa is generated by

agriculture. Crop production and livestock husbandry account for about half of household income. The poorest members of society are those who are most dependent on agriculture for jobs and income (Odingo, 1990; FAO, 1999).

### **2.6.3 Climate Change and Agriculture**

Agriculture is a climate sensitive sector and will be affected by climate change, potentially both positively and negatively. Temperature and other climatic changes will affect yield and growing season and there is a potentially direct (positive) CO<sub>2</sub> fertilization effect. Given much of Kenyan agriculture is currently rain-fed; there are also potentially wide ranging effects from the potential changes in precipitation. Moreover, there are a number of complex interactions with other factors, e.g. extreme events (heat, floods, and droughts), soil, pests and diseases, and complex interactions with other key sectors, e.g. water availability for irrigation, which will affect the sector. Any responses will be differentiated between parts of the country. They are also very much influenced by responses and agricultural management (autonomous reactions). The net effects of all these changes are extremely hard to predict. In the face of this complexity, it is impossible to predict future climate change impacts in Kenya.

In considering the role of agriculture with respect to climate change, it is important to consider the impact of agricultural practices on climate change. For example, the type of vegetation, method of tillage, amount of land cover, type of windbreak and type of irrigation system are all factors that influence the microclimate and macroclimate either directly or indirectly, whether by changing transpiration, particles in the air (dust, soot), precipitation, wind, etc. These changes can alter the global climate if the energy budget at the earth's surface is significantly changed. The main source of energy at the earth's surface is the incoming solar radiation. Some forcing agents, such as greenhouse gases (GHGs), cause warming whereas others, such as increased reflectivity of the surface (albedo) and aerosols, mainly cause cooling.

In the past 20 years, about 75% of the CO<sub>2</sub> emissions have been attributed to fossil fuel burning and the remainder to land-use change (IPCC, 2001b). The major impacts of agricultural land-use change are occurring in tropical rainforest regions such as Brazil, Congo, and Indonesia where native rainforests are being cleared for cultivation and pasture. Tropical deforestation, which now exceeds 13 Mha per year (World Resource Institute,

2000) is a substantial source of CO<sub>2</sub>. It also causes a moderate increase in albedo, which causes cooling of the air; however, this cooling is more than offset by a warming of the air through a reduction in evapotranspiration and through CO<sub>2</sub> emissions associated with deforestation.

Through agricultural activities e.g. land clearing, cultivation of annual crops, irrigation, grazing of domesticated animals; humans are extensively altering the local, national and global land-cover characteristics, including physiological and physical characteristics. It is generally accepted that the expansion of agriculture into natural ecosystems has had a significant climate impact. (Lobell *et al.*, 2006) used the National Center for Atmospheric Research (NCAR) general circulation model to demonstrate that a reduction in tillage can have a significant cooling effect by increasing the albedo. The NCAR model predicted that increases in soil albedo by reduced tillage have a potential global cooling effect of 0.2°C. This value is comparable to the biogeochemical cooling from the expected global soil carbon sequestration potential. Boucher *et al.*, (2004) examined the human influence of irrigation on atmospheric water vapor and climate. They estimated a global mean radiative forcing in the range of 0.03 to 0.1<sup>2</sup> Wm due to the increase in water vapor in the atmosphere, but a cooling of up to 0.8<sup>0</sup>C over irrigated areas.

There are approximately 1.4 billion hectares of farmland in the world today (FAO, 2003). Currently, the potential for further expansion of agricultural lands is limited because most of the good-quality arable land is already under cultivation. There is some limited potential to expand agricultural lands in humid tropical regions (FAO, 2003), but these areas have major limitations due to steep slope, stoniness, soil depth and poor natural fertility. With increasing population, agricultural lands are likely to come under increasing pressure. Emerging carbon-credit market and bio-fuel incentives may encourage producers to intensify agricultural practices to enhance productivity.

Some expansion is then likely to occur onto marginal land. This is likely to lead to land degradation and, in some instances, desertification. Land degradation has already taken place in many regions of the world because of dramatic changes in agricultural practices during the last several decades (Sivakumar, 2007). The obvious impact of land degradation is an increase in surface temperature and a decrease in latent heat flux, but actual changes

are much more complex. The impacts affect regional atmospheric circulation far beyond the region involved (Werthand Avissar, 2002).

Fortunately, agriculture also offers major potential for mitigation. The only way to halt the release of climate change gases caused by land conversion is to halt land conversion and forest destruction. This means our consumption, especially in the rich countries, must be reduced to curb pressure on newly converted land. Meat consumption must be slashed because meat production draws heavily on feed production that consumes huge areas of land (e.g. soybeans and corn). First generation bio-fuel production must also be abandoned as it combines huge land-use and offers no real carbon gain. The Fourth Assessment of the IPCC (2007) recommends mitigation measures on crop rotation and design, nutrient management, livestock growing and also maintaining fertile soils.

#### **2.6.4 Climate Change Implication on Health**

Climate change has critical health implications. Changes in rainfall will affect the presence and absence of vector- and water-borne pathogens (IPCC, 2001). For example, it can be expected that small changes in temperature and precipitation will boost the population of disease-carrying mosquitoes and result in increased malaria epidemics (Lindsay and Martens, 1998). Increased flooding could facilitate the breeding of these malaria carriers in formerly arid areas (Warsame *et al.*, 1995). These problems will be exacerbated by the inability of many communities to cope with increased disease.

In many African urban settlements, population expansion has outpaced the capacity of municipal authorities to provide civic works for sanitation and other health delivery services. If settlement conglomerations such as those envisaged for West Africa and the eastern seaboard of South Africa develop, vulnerable populations will cover entire regions, not just isolated areas (Nicholls *et al.*, 1999). Semi-arid areas of the Sahel, the Kalahari, and the Karoo historically have supported nomadic societies that migrate in response to annual and seasonal rainfall variations. Nomadic pastoral systems are intrinsically able to adapt to fluctuating and extreme climates - if they have sufficient scope for movement and other necessary elements in the system remain in place.

However, the pro longed drying trend in the Sahel since the 1970s has demonstrated the vulnerability of such groups to climate change: they cannot simply move their axis of migration when the wetter end already is densely occupied and permanent water points fail

at the drier end. The result has been widespread loss of human life and livestock, and substantial changes to the social system.

Malaria is especially susceptible to changes in the environment as both the pathogen (*Plasmodium*) and its vector (mosquitoes) lack the mechanisms necessary to regulate internal temperature and fluid levels. This implies that there is a limited range of climatic conditions within which the pathogen and vector can survive, reproduce and infect hosts (Patzet *et al.*, 2003).

Vector-borne diseases, such as malaria, have distinctive characteristics that determine pathogenicity. These include the survival and reproduction rate of the vector, the level of vector activity (i.e. the biting or feeding rate), and the development and reproduction rate of the pathogen within the vector or host (Patz *et al.*, 2003). These depend on climatic conditions such as temperature, precipitation and humidity. The ideal temperature range for malaria-carrying mosquitoes is 15–30°C. Temperature exerts varied effects on survival and reproduction rate of mosquitoes. If initial temperature is high, then an increase in average temperature, associated with global warming, can decrease the survival and reproduction rate of mosquitoes.

Mosquitoes are also highly sensitive to changes in precipitation and humidity. Increased precipitation can increase mosquito population indirectly by expanding larval habitat and food supply. Mosquitoes are, however, highly dependent on humidity, surviving only within a limited humidity range of 55-80%. Infectious disease often accompanies extreme weather events, such as floods, earthquakes and drought. These local epidemics occur due to loss of infrastructure, such as hospitals and sanitation services, but also because of changes in local ecology and environment. For example, malaria outbreaks have been strongly associated with the El Nino cycles of a number of countries (like Kenya, India).

El Nino can lead to drastic, though temporary, changes in the environment such as temperature fluctuations and flash floods (Epstein, 2002). In addition, with global warming, there has been a marked trend towards more variable and anomalous weather. This has led to an increase in the number and severity of extreme weather events. This trend towards more variability and fluctuation is perhaps more important, in terms of its impact on human health, than that of a gradual and long-term trend towards higher average temperature (Epstein, 2002).

## **2.7 Impact on Development and the Economy**

The economic sector is vulnerable to climate change sensitivity with huge economic impacts. This vulnerability is exacerbated by existing developmental challenges of endemic poverty; complex governance and institutional dimensions; limited access to capital including markets; inadequate infrastructural and technological development; ecosystem degradation and complex natural disasters (IPCC, 2007a). In Kenya, the economic sector is mainly agriculture - driven thus sensitive to change in this sector. Climate change is/will negatively affecting/affect food production especially tea production in the Kenya Highlands which is sensitive to temperature and rainfall in turn affecting income from the leading foreign exchange earner (FAO, 2002).

Kenya is a developing country whose growth model like many developing nations is based on the economic growth model that largely favors economic, industrial and physical development at the cost of environmental management. Thus, the current economic situation and state of the environment in Kenya has weakened the capacity of the country to adjust to the drastic economic and ecological changes are/will be induced and/or enhanced by climate change (Ominde and Juma, 1991). Coupled with this is the fact that over 80 % of the population depends on agriculture as their livelihood. Hence, the challenge is how to share the insufficient economic resources to combat climate change and shift the overdependence of such a large populace from agriculture to alternative livelihood support mechanisms.

Over 40 percent of the Kenyan population is food poor while another 30 percent is poor living on less than USD 1 per day (Kenya, 2006). The poor are often located in high-risk marginal areas and their lack of socio-economic resources means that they are ill equipped to adjust to the long-term changes in climate. In addition, poverty undermines the health status of the people. Therefore, climate change will increase the poor's vulnerability and reduce their adaptive capacity. Demand for bio-fuels poses a threat to forest lands and arable land thereby increasing food insecurity. With increased GHG emissions, high-energy costs of fossil fuel and energy insecurity, the world is turning to alternative sources of energy to meet their energy needs. Although the past two decades have seen increased progress in developing alternative energy, these technologies have not reached a level where they can replace conventional sources of energy.

## 2.8 Extreme Events and Natural Disasters

Over 70 percent of natural disasters in Kenya are weather-related and their frequency has increased over the years with drought and floods being the main disasters (Kenya, 2006). The drought oscillation period in past years recurred every 5 years but has now reduced to every 2 to 3 years. The worst drought since independence was in 1991- 92 while the 1997-2000 was the worst in the past 40 years. During the latter drought, nomadic communities incurred over 50 percent losses in livestock while food shortages were felt countrywide. In 2008/09, Kenya faced one of the worst droughts that left over 10 million people without food and access to drinking water (National Food Security Status and Required Interventions, 2009).

This disaster was exacerbated by a combination of other factors including the 2007/8 post-election violence that affected agricultural production in Kenya's bread basket areas, global economic recession that affected the purchasing power of the people, and inadequate disaster response mechanism which is often disaster response rather than prevention and other governance issues. The worst floods in Kenya occurred in 1997/98 El - Nino rains that resulted in displacement of persons, damage of physical infrastructure such as roads, bridges and railways, spread of human and livestock diseases *viz* cholera, malaria and Rift Valley Fever diseases respectively, damage to agricultural produce and economic fiscal inflation. Climate change is predicted to enhance drought, flood, fire, ENSO and tropical storms within the country and along the Coastal zone (National Food Security Status and Required Interventions, 2009).

Even in the absence of climate change, the economic costs of the periodic floods and droughts that affect Kenya could rise significantly in future years, due to socio-economic change (population and economic growth). In the absence of adaptation, these drivers could increase the costs of events by a factor of five by 2030, that is a periodic large-scale event could have direct economic costs of \$5 to 10 billion. A key priority therefore is to increase the resilience of Kenya to cope with these extreme events.

Climate change is likely to further increase the economic costs of these events. Many of the projections indicate a change in heavy precipitation events for Kenya. These increases in intensity would increase the economic costs of periodic flood events significantly, because the costs rise very sharply with flood depth and strength. They would also mean a reduction

in the return period of larger events, i.e. more significant floods could occur more frequently. Even on yearly basis, these indicate significant increases in economic costs. The effects on droughts are more uncertain, but the range of model projections does include changes that would exacerbate existing periodic events for some regions of the country, which would further increase economic costs.

## **2.9 Efforts Made Towards Combating Climate Change in Kenya**

Ratification of the Kyoto Protocol: Kenya ratified the Kyoto Protocol of the United Nations Framework Convention on Climate Change (UNFCCC), in August 1994 and has over the years actively participated in and hosted the Conference of Parties (Goldemberg *et al.*, 1996). The country has also operationalized the implementation of target objectives and agreements albeit at lower scale due to socio - economic challenges.

The Government has also set modalities for participation in the Clean Development Mechanism (CDM), one of the flexible mechanisms of article 12 of the Kyoto Protocol that allows industrialized countries (Annex I countries) to finance investment projects for greenhouse gas emission reduction in developing countries so as to generate credits which can be used to meet their own commitment to the Protocol. In this regard, relevant ministries and state corporations in Kenya are in charge of major components of the CDM through licensing, inspection, monitoring and approval of related projects. (Goldemberg *et al.*, 1996).

However, institutions in Kenya have been operating on crossroads' in resources conservation and curbing climate change. For example, NEMA a government parastatal established to exercise general supervision and co-ordination over all matters relating to the environment has done little in enforcement and compliance of the Kyoto protocol aimed at reducing the levels of carbon emissions. The ultimate objective of UNFCCC Convention is "Stabilization of the greenhouse gas concentration in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system" (Gupta, *et al.*, 2007).

Kenya Forestry Research Institute's mission is to contribute, together with its partners, to forestry and agricultural innovations and knowledge towards improved livelihoods and commercialization of agriculture and forestry through increasing productivity and fostering value-chains while conserving the environment. The Kenya Agricultural Research Institute (KARI) bringing together research programmes in food crops, horticultural and industrial

crops, livestock and range management, land and water management, and socio-economics. KARI promotes sound agricultural research, technology generation and dissemination to ensure food security through improved productivity and environmental conservation.

### **2.10 Climate Change Issues in Kenya**

The challenge for Kenya is to develop strategies, which would promote sustainable development, without compromising in increased emission of GHGs. It is necessary therefore to develop appropriate policies and response strategies to manage GHG emissions. Policies and strategies must be based on reliable inventory of GHG emissions and sinks. The First National Communication of Kenya is the main output of the enabling activity project. The Ministry of Environment and Natural Resources through the National Environment Secretariat (now NEMA) executed the Climate Change Enabling Activity.

Four thematic areas need to be identified in accordance with the UNFCCC guidelines for the preparation of Non-Annex 1 national communication. This includes:- National GHG Inventory, Abatement, Sinks and Sequestration, Vulnerability and Adaptation to Climate Change, Research and Systematic Observation, Awareness and understanding of climate change issue, Clean Development Mechanism, Transfer of Environmentally Sound Technologies, Climate Change Mitigation Strategies and Policy Frameworks, Convention Negotiation Capacity including issues of Equity.

Kenya Forest Working Group is a gathering of individuals and organizations (government and non-government, local, national and international) concerned with forests, their conservation and management. KFWG was formed in 1995 to provide a forum for exchanging and sharing information and experiences among members. Although it exists as a sub-committee of the East African Wild Life Society, it has done a commendable job by trying to bring on board various stakeholders in curbing climate change through forestry. This has been achieved through improving the status of Kenya's forests.

### **2.11 Decentralization of Forest Resources**

Decentralization refers to 'any act by which a central government cedes rights of decision making over resources to actors and institutions at lower levels in a politico-administrative and territorial hierarchy (Blaser, 2005; Meinzen-Dick and Knox, 2001).

A large number of reasons have been given for shifting locus of decision making and resource management away from central states to local governments or communities. State control was found largely unsuccessful, costly and financially unsustainable (Meinzen-Dick-Knox, 2001; Shackleton, 1999). Because they are often directly dependent on the resource, they are assumed to have greatest incentives to maintain the resource base over time. The policy move towards greater local control is reflected in a wide range of community-based arrangements in the natural resources sector over the past decade (Barrow and Murphree, 2001; Barrow *et al.*, 2000; Hulme and Murphree, 2001; Shackleton, 1999).

These changes in approaches to natural resources management have not occurred in isolation; they continue to be part of wider processes of democratization and decentralization within policies. Arguments for these wider processes are similar to those advocated by NRM scholars and practitioners. Making lower-level officials responsible for the provision of a wide variety of goods and services should result in more efficient, flexible, equitable, accountable, and participatory government because the costs and benefits of local service provision will be better linked (Oates, 1972, World Bank, 1988, Rivlin, 1992, Maro, 1990, Inman and Rubinfeld, 1997, Ferejohn and Weingast, 1997).

By 'bringing the state closer to the people' decentralization is also expected to increase local participation. In addition, poverty alleviation is often cited as a related and expected overarching outcome of such reforms.

Agrawal and Ostrom (2001), suggest that to better understand the resource management outcomes of decentralization programs it is worthwhile to examine the rights and capacities that are transferred to actors at lower levels. These will impact on the benefits that lower level actors may have to sustain the resources, and subsequently their incentives for sustainable management.

Decentralization in the forestry sector comes to Kenya rather late in the game, with enabling legislation only having been approved in 2005. This article analyzes the character and content of interactions between actors in the forestry sector in Kenya and Uganda, in both pre and post reform settings. In particular it explores the range and nature of decisions that laws and policies allow the different actors to take and those decisions that these actors actually take in practice. It also assesses whether pre and post reform structures and processes provide positive incentives, especially to forest resource users.

Under control of the Forestry Department (FD), several management programs exist. These included the 'shamba system' in which farmers were permitted to cultivate on clear cut land in return for tending saplings planted by the department. This system was dropped in the 1980's due to widespread abuses of the program by local farmers, and instead tea belts were planted at the edges of some parts of the forest to buffer against further deforestation.

In later years management focus expanded from law enforcement, licensing of permitted extraction of forest produce, control of problem animals, maintenance of infrastructure such as trails, roads and buildings, and education and tourism development, to attempting some community inclusion under a pilot program between 1990 and 1992 supported by the Kenya Indigenous Forest Conservation Project of the UK Overseas Development Administration (ODA). Under this plan, Kakamega Forest was divided into four sub zones: protected zone, rehabilitation zone, subsistence zone and plantation zone. There are several grass roots conservation organizations which are involved in Environmental Education, in tree nursery development and in the protection of biodiversity.

Thus the profiles of forests are very similar. Both are high value, high biodiversity forests, located in areas of high population densities and in close proximity to major urban areas. In addition, local communities practice subsistence agriculture and are highly dependent on forest for various products as sources of income and also to meet their subsistence and energy needs. Forest management in both forest areas face the challenge of balancing multiple uses and needs and management has adopted a zoning procedure.

### **2.11.1 Forest Management after Decentralization in Kenya**

Unlike Uganda, Kenya's reform of the forestry sector is very recent. A key motivator has been the very rapid decline of the extent of the forest estate (about 8% in the 1990s) and some recognition of the roles of local communities in management. The Forest Act of 2005 provides for the development of new institutions and partnerships for improved forest management. The previous Forest Department was in May of 2006 replaced with a Kenya Forests Service, mandated with the development of partnerships for sustainable forest management.

Kenya Forests Service is in the process of developing participatory forest management plans for all forest areas in the country in close consultation with Forest Associations and gender-balanced local forest management committees. This is a major break from prior

policy and practice, which was authoritarian and failed to recognize the role of different actors. In addition, new rules are being formulated to enhance the processing and marketing of forest products. The Act also allows non-residential cultivation by community members in areas intended for establishment of industrial plantations.

The plots allocated would be a minimum of a quarter of an acre and preferences for allocation would be given to the poor and the vulnerable members of the community. This is yet again another break from the previous forest act, which was ambiguous and thus caused the Forest Department to oscillate between plot allocation and eviction in between general election years. The effort to decentralize is thus cognizant of the equity dimension of forest management (in addition to sustainability), and makes clear reference to the poor and vulnerable groups in communities, including women, the disabled, youth and children.

### **2.11.2 Beneficiaries of Decentralization of forest management in Kenya**

Because the reform of the forestry sector is still in its infancy, an analysis of the implications is tenuous. However, according to the law, the targeted beneficiaries are local communities and private entrepreneurs. The Forest Act recognizes the central position of forests in the livelihoods of the rural communities and proposes measures to enhance community participation in forest conservation as follows:

They encourage sustainable use of forest resources by communities, support the establishment of community forests through which communities can be able to participate in the conservation and management of forests. Moreover, they protect the traditional interests of local communities customarily resident within and around forests and recognize cultural practices that are compatible with sustainable forest management.

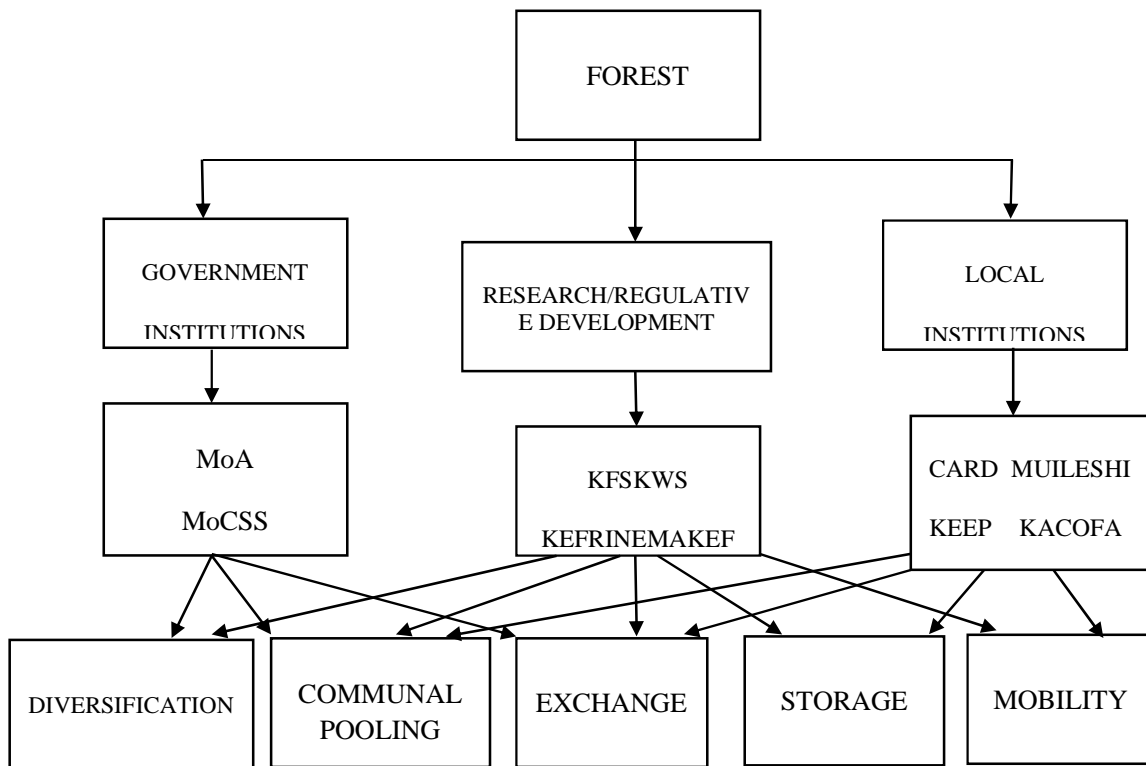
The Act also recognizes the importance of marginalized groups especially youth and women in forest conservation and proposes strategies to address their inclusion as follows:

They enhance training and education opportunities in forestry for the youth and women; endeavor to deliberately involve youth and women in participatory forest management and encourage the youth to take more responsibility in the management of forests to ensure that future generations are catered for when decisions affecting forests are made. These benefits are however subject to formal organization, the creation of committees and associations, the

adoption of constitutions and the drawing of management plans. It also provides for the compensation of any takings.

**2.12. Stakeholder Organization and their linkages for sound collective action**

In Kakamega Forest, the institutions/ stakeholders involved either directly or indirectly in conservation and management are; Ministry of Agriculture- MoA, Ministry of Culture and Social Services - MoCSS, Community Based Organizations - CBO, Kenya Forest Service - KFS, Kenya Wildlife Service - KWS, National Environmental Management Authority - NEMA, Kenya Forestry Research Institute - KEFRI, Community Action for Rural Development - CARD, International Centre for Insect Physiology and Ecology - ICIPE, International Centre for Research and Agro Forestry - ICRAF, Kakamega Environmental Education Programme - KEEP, and Kakamega Community Forest Association –KACOFA.



**Figure 2.1:** The interaction of the three categories of institutions and how they affect each other based on roles. Arun Agrawal and Catherine McSweeney, 2008, *The Social Dimensions Of Climate Change*, No113.

Figure 2.1 above shows a matrix of the five classes depicting the flow and linkages of institutions, interventions for the best practices and sound collective action. The research and government institutions have three major tasks in the formulation of the management outcomes. Diversification, communal pooling and exchange of information are the key roles that are played by the two. The local institutions are important in mobility and storage of both the resource and knowledge that greatly shows their high capability in resource conservation.

## CHAPTER THREE: METHODOLOGY

### 3.1 Description of the Study Area

The study was conducted in Kakamega Forest and its environs that fall within Kakamega County in Western region of Kenya. Kakamega town neighboring Kakamega forest has a population of 1,660,651 according to 2009 census. The average elevation of Kakamega is 1,535 meters above sea level. Kakamega County is Kenya's second most populous county after Nairobi. ([http://www.scribd.com/doc/36672705/Kenya-Census-\(2009\)](http://www.scribd.com/doc/36672705/Kenya-Census-(2009))). Local inhabitants are mostly the Luhya tribe, whose economic activity is mainly farming. Kakamega County serves as the headquarters of Kenya's largest sugar producing firm, Mumias Sugar, located in Mumias.

Kakamega Forest is a major tourist destination in the region. The Kakamega Forest ecosystem plays a critical role as one of Kenya's water catchment areas. Kakamega forest receives some of the highest rainfall in the country and annual average precipitation is 2000 millimeters, and is largely reliable for agricultural production. The long rains are between April and November, with a short dry season from December to March. Rain falls mostly in the afternoon or early evenings and is often accompanied by heavy thunderstorms. The temperatures do not vary greatly throughout the year, with a mean maximum shade figure of 26<sup>0</sup> C and a mean minimum of 11<sup>0</sup> C. During daytime Kakamega can be quite hot and humid. The nights and early mornings can be surprisingly chilly.

The forest has three distinct canopy layers i.e. upper storey with an average height of between 30 and 50 metres. List of various species are shown on table 3.1 below.

**Table 3.1 Trees with an average height between 30 and 50 metres**

<b>Species</b>	<b>Local name</b>
<i>Brideliamicrantha</i>	Shikanganya
<i>Croton megalocarpus</i>	Musine
<i>Harunganamadagascariensis</i>	Namalasike
<i>Psydraxschimperiana</i>	Lango, Kango
<i>Zanthoxylumgilletii</i>	Shikhomia

**Source: Seed Centre - KEFRI**

Middle storey has an average height of between 15 and 30 metres. These species are shown on table 3.2 below.

**Table 3.2: Trees with an average height between 15 to 30 metres**

Species	Local name
<i>Aningeriaaltissima</i>	Makangu
<i>Oleacapensis</i>	Omutukuyu

**Source: Seed Centre - KEFRI**

The lower storey has an average height of 10 metres and the species shown on table 3.3 below.

**Table 3.3: Trees with an average height of 10 metres**

Species	Local name
<i>CeltisAfricana</i>	Mwenya
<i>Tecleanobilis</i>	Kumutare, Mutaro
<i>Psidiumguajava</i> ,	Lipera
<i>Acacia abyssinica</i> ,	Munyenya

**Source: Seed Centre - KEFRI**

Most species in the forest have a patchy distribution. A few species were well distributed i.e. occurring in almost half of the 30 plots sampled. These species are shown on table 3.4 below.

**Table 3.4: Trees patchy distributed in all 30 plots**

Species	Local name
<i>Antiaristoxicaria</i> ,	Mulundu
<i>Ficussur</i> ,	Musingu
<i>Polysciasfulva</i>	Mwanzu

**Source: Seed Centre - KEFRI**

Others which were fairly distributed were occurring in between 5 and 10 plots are shown on table 3.5 below.

**Table 3.5: Trees fairly distributed between 5 and 10 plots**

Species	Local name
<i>Blighiaunijugata</i>	Shiarambatsa
<i>FuntumiaAfricana</i>	Mutondo
<i>Funtumialatifolia</i>	Mutondo
<i>Maesopsiseminii</i>	Mutere, Muhunya
<i>Spathodeanilotica</i>	Mutsurio, Mutsulia
<i>Bequaertiodendronnatalense</i>	Musamia

**Source: Seed Centre - KEFRI**

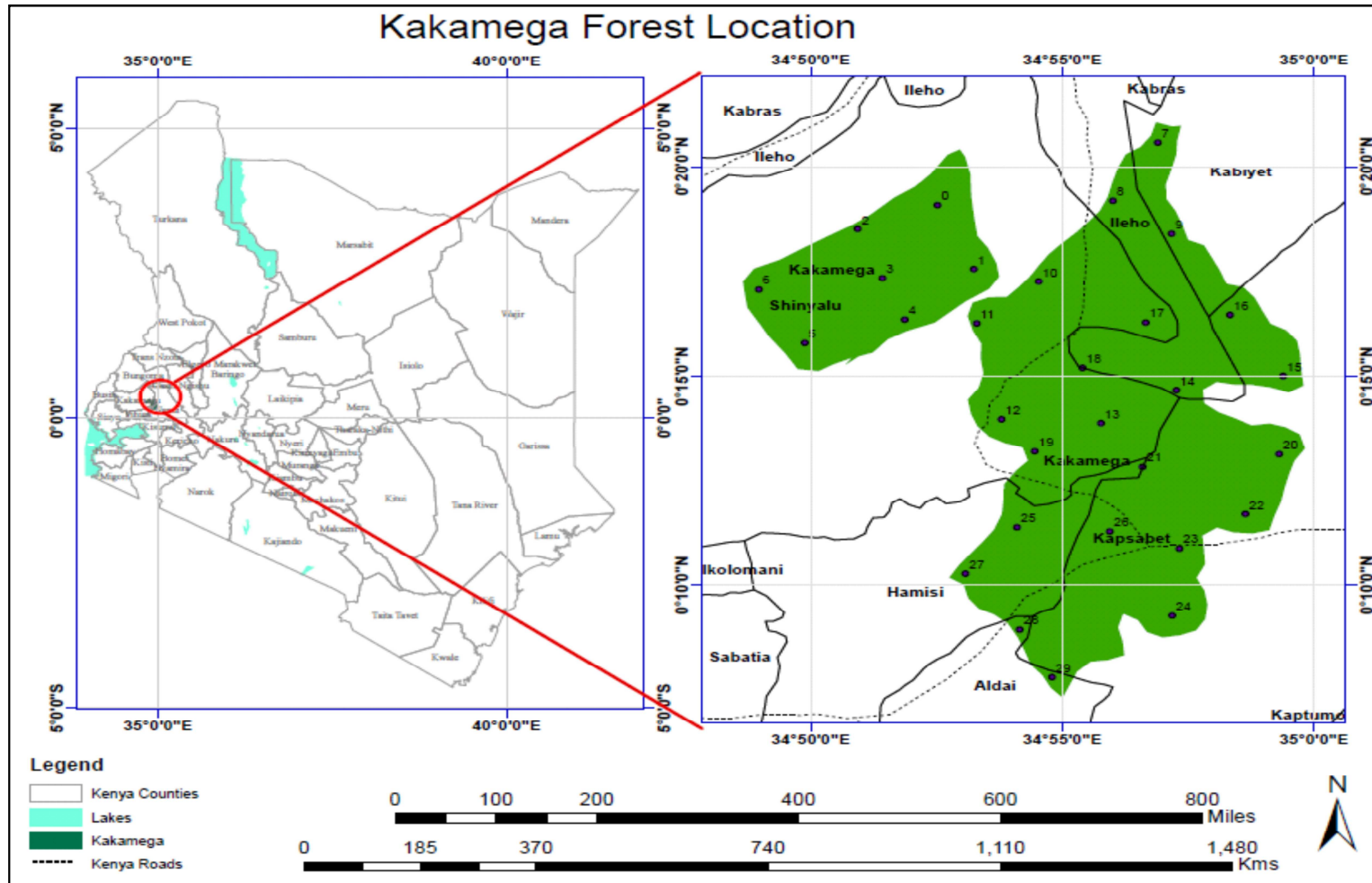


Figure 3.1: Location map of Kakamega forest (adopted from GIS department, KEFRI)

### **3.2 Research Design**

The study used descriptive design. It defined the problem of how institutions were working together to mitigate climate change through decentralization of forest resources. Primary data were obtained from both Kakamega natural forest and Kakamega Community Forest Associations whereby biodiversity species were identified. This was done using a structured questionnaire that was designed to capture all the objectives of the study. Secondary data were collected and analyzed from all institutions that are responsible for the conservation and management of the forest. Social economic and dependence to the forest was done using interviews.

### **3.3 Sampling Procedure**

Stratified random sampling inside the forest arrived at the number of plots used for this study. A topographical map was sourced from the surveys of Kenya and assisted in randomizing these plots. This was used to determine the condition of the forest and assisted in understanding the interaction of institutions and the forest. The number of respondents interviewed was determined by the number of Community Forest Association working around Kakamega Forest within a radius of five kilometers from the forest edge. CFAs included CACOFA, KEEP, CARD, Muileshi CFA, Bunyala CFA, Malava CFA, Kibiri CFA and Isukha heritage.

### **3.4 Sample Size**

Due to the enormous amount of data collected in a single plot, the work load per plot and limitation of resources, the researcher randomly selected 30 concentric plots as a representative sample of the whole forest. The plots were arranged in intervals of 200 meters and their coordinated are indicated in the appendix. This assisted the researcher in determining the state of the forest in terms of biological diversity contained in the forest (flora and fauna). Trees, herbs, seedlings, shrubs, saplings and regeneration were identified and recorded in the inner circles of (1, 3 and 10 respectively) within the same plot.

The social economic, dependence on the forest by the community adjacent to the forest and policies influencing outcome in adapting to climate change was attained by cautiously guided interviews which ensured that all members were represented. The interviewees were 50 and this included farmers, herbalists, business class people, zonal managers, forest guards, wildlife guards and youth along the 5 kilometer stretch from the edge of the forest.

The interviewees were arrived at through holding a meeting with members of the community forest associations working in the forest, KFS and KWS officials. Most of the CFA members were farmers, youths and herbalists. There were 24 farmers, 6 herbalists, 4 business class people, 10 youths living adjacent to the forest, 2 zonal manager officials from KFS, 2 forest guards and 2 wildlife officials from KWS. The business class people were neither members of KWS, KFS or CFAs but they use resource in the forest.

### **3.5 Instruments**

The research tools that were used for this study were questionnaire and interviews. The questionnaire was used to collect data from various institutions on matters of forest use and conservation efforts. The interviews were used to record community forest association information and from institutions on forest species diversity (flora and fauna) as explained in the sample size.

### **3.6 Data Analysis**

The first stage of data analysis was data cleaning. The questionnaire was examined to ensure that it was complete and had been consistently filled in. The data were then coded and summary tables prepared on all the responses. Descriptive statistical techniques were important because they provided crucial summaries related to data. Descriptive measures such as frequencies, percentages, mean scores, standard deviation, cross tabulations and charts were derived from the responses to summarize data from various variables. The correlation between gender, age and level of education was carried out to determine how social economic factors influence the relationship of the community and the forest. This was mostly done using Statistical Package for Social Sciences (SPSS) and Microsoft Excel package.

## CHAPTER FOUR: RESULTS AND DISCUSSIONS

### 4.1 Introduction

This chapter gives a detailed report of key research findings with the analysis and discussions of the study area in depth. Discussions and presentations have been captured according to the objectives that include an evaluation of the policies that influence outcomes in adapting to climate change, to analyze the roles played by Kenya Forest Service and Kenya Wildlife Service in mitigating climate change and to find out if decentralization of forest resources meets the goals of sustainability. The tools used to analyze data were spreadsheets and statistical package for social sciences. Discussions are made based on the information contained on the implication of the findings cited linking it to all sections of the study from the background, the objectives and literature reviewed.

### 4.2 Sex of Respondents

A total of 50 respondents were interviewed. This number was derived from the total respondents, 84%, (n = 42) were male and only 16 %, (n = 8) were female as shown in Table 4.1 below. Men and women had a mean of 1.16 (SD = 0.370). Male gender of the household in any rural household determines the major decision maker in all issues in the household. More males were interviewed than females because they are the household heads and in most cases have the mandate to access the forest resources than female.

During the interview day, a meeting was called and more males turned out than females and the reason was that females were left at home to do household chores and look after children. Male and female - headed households have different access to and control over resources such as labour, capital, credit, land, and even trees as noted by Kokwaro (1988) in his study of Kakamega Forest. The accessibility and use of forest products are also largely determined by gender in Luhya. These include communities like Idakho, Isukha, Kabras, Khalo, Marama and Marachias it was observed by Dose (2005).

**Table 4.1: Sex of the Respondents**

<b>Sex of the respondents</b>	<b>Frequency</b>	<b>Percentage (%)</b>
Male	42	84
Female	8	16
<b>Total</b>	<b>50</b>	<b>100</b>

**Source: Author 2012**

Traditions and culture in many parts of Kenya especially the Western part of Kenya where this study was undertaken have a large impact on tree planting activities and in many

communities; tree-related activities are regarded as a purely male domain. Other than access and control, in general, female-headed households also have fewer resources as compared to male-headed households.

### 4.3 Age of Respondents

The age of the respondents varied between 15 to 76 years. The highest number of individuals fell in the age category of 46 to 55 years (36%) as shown in Table 4.2 below. This is probably because most individuals under this age have more access to forest resources than any other age category. More so, they have experience in forest conservation and use in terms of harvesting forest products such as honey, wild fruits, firewood, timber and non timber forest products, planting of trees and also practising of plantation establishment and livelihood improvement scheme (PELIS). The scheme helps them earn money that helps improve their standard of living.

The table shows that ages between 15–25 years had 8%, (n = 4) meaning that most of these respondents were in school from primary to tertiary. They do not have much time to access the forest products as they concentrate in their studies. Respondents represented by age 66 and over are the least represented by 6% and most of them do not have energy to access to forest products as most of them are taken care of by the middle class 36 – 45 years that is the youth. In this case, with the new decentralized policy, the older respondents are more likely to be involved in planning and coordinating forestry activities within the village than the younger ones. They are therefore likely to benefit more from the decentralization process than the younger respondents.

**Table 4.2: Age of Respondents**

<b>Age of the respondents (Yrs)</b>	<b>Frequency</b>	<b>Percentage (%)</b>
15–25	4	8
26–35	7	14
36–45	13	26
46–55	18	36
56–65	5	10
66 and over	3	6
<b>Total</b>	<b>50</b>	<b>100</b>

**Source: Author 2012**

#### 4.4. Education Levels of Respondent

Table 4.3 below shows that on average, most members of the community have had some formal education. A majority 69%, (n = 34) of the respondents had completed eight years of formal education coded as 1-primary education and very few had college and university level of education coded as 3-tertiary as shown in the table. A few had not undertaken any formal learning. On associating number of years completed in undertaking formal education and the sex of head of household, this implied that both male and female respondents had taken almost an equal number of years in completing their formal education.

Of the respondents interviewed, 12%, (n = 6) did not have any formal education. Most of the respondents interviewed who had attained 9 - 12 years of formal education were represented by 14% (n = 7). This meant that after 8 years of formal education, most of the respondents do not continue with education but drop out of school to do businesses of depending on the forest resource for livelihood. The activities they do includes harvesting of forest products for building materials, charcoal burning for sale and use in homes and clearing of forest area for settlement and agricultural purposes.

**Table 4.3: Education Levels of the Respondents**

<b>Number of years completed in formal education (Yrs)</b>	<b>Frequency</b>	<b>Percentage (%)</b>
None	6	12
Primary (1 – 8)	34	69
Secondary (9 – 12)	7	14
Tertiary (13 and above)	3	5
<b>Total</b>	<b>50</b>	<b>100</b>

**Source: Author 2012**

The level of education is an important variable to consider within the forestry resource. Maurer, et al., (2007), has found a similar finding on level of education and unemployment. It is widely believed that the higher the level of education of a person, the more receptive he/she is to changes, and therefore the more likely he/she is to undertake forest conservation activities as indicated by Dose, (2005). Older people are often more conservative and more set in their ways of doing things. Education may also open up minds to the importance of

conserving and sustainably managing the forest resource. On the other hand, the higher the level of education of an individual the less dependent they are on the forest.

It is therefore generally considered that higher levels of education often lead to less degradation of forest resources occurring within close proximity of such individuals since they have and use alternative sources of livelihoods from those offered by the forest. Some of the products consumed by the educated people are world fruits, building materials, charcoal among others from the less educated counterparts. They sell to them because they do not have enough time to go to forest and harvest products as they do other economic activities either salaried jobs or businesses making a living out of it.

#### 4.5. Languages spoken in Kakamega

Most of the respondents interviewed were from Luhya community. Up to 96 % (n = 48) of the respondents belonged to the largest dialect locally known as ‘Isukha’ which is a sub - tribe of the Luhya while 2% (n = 1) of the respondents spoke English and 2% (n = 1) spoke Kiswahili as shown by Table 4.4. The variable is important for issues related to collective action. When a group is highly homogenous, there is a high likelihood that they would be willing to take action as a single group and therefore the chances of succeeding in any given activity are high. However, a group that is highly heterogeneous may have more problems due to different interest groups therefore making it more difficult to achieve given goals especially in forest resource conservation.

**Table 4.4: Languages Spoken in Kakamega**

<b>Languages Spoken</b>	<b>Frequency (n)</b>	<b>Percentage (%)</b>
Luhya	48	96
English	1	2
Kiswahili	1	2
<b>Total</b>	<b>50</b>	<b>100</b>

**Source: Author 2012**

#### 4.6. Forest Status

As shown on Table 4.5 below, 74 % (n = 37) of the respondents lived adjacent to the forest and acknowledged that forest cover is decreasing. Respondents, 18 % (n = 9) felt that the forest cover has not changed, while the rest 8 % (n = 4) felt that the forest cover has

increased. The distribution of male and female respondents was significantly associated (Chi square test = 8.049; DF= 2; p= 0.018) with what they said about the status of the forest.

Forest cross tabulation was used to compare forest status for the past ten years and gender was used to give this information. Among the reasons cited for the deteriorated condition of the forest were given by 74% of the respondents that included; increasing population growth and therefore increased harvesting of forest products for building materials, charcoal burning and excision clearing of forested area for settlement and agricultural farmland.

**Table 4.5: Forest Coverage as Rated by Respondents**

Status of the Forest	Frequency	Percentage of respondents
		(%)
Increasing	4	8
Decreasing	37	74
No change	9	18
<b>Total</b>	<b>50</b>	<b>100</b>

**Source: Author 2012**

Increase in population has directly affected climate change in that due to harvesting of forest products such as firewood, wood logs for electric poles and building materials, timber, honey, wild fruits among others, the forest decreased affecting the water tower that act as a source of water to most residents in Kakamega and parts of western Kenya. This also affected habitat of most animal species that have died and others migrated to other favorable habitats. Among the reasons given, reduction of forest cover also affects climate through increased carbon in the atmosphere as trees act as carbon sinks for carbon sequestration and thus causing global warming as noted by Birdsey (1996).

#### **4.7. Frequency of Entry to the Forest**

The frequency of forest entry is largely attributed to collection of forest products, recreational activities, cultural rituals, eco-tourism, camping among others.

The respondents who entered daily were 68% (n = 34) those who entered weekly were 14% (n = 7) those who entered on monthly basis were 8% (n = 4) and those who never visited forest were 10% (n = 5).

**Table 4.6: Frequency of Entry to the Forest**

<b>Time</b>	<b>Entry to the Forest</b>	
	<b>Frequency</b>	<b>Percentage (%)</b>
Daily	34	68
Weekly	7	14
Monthly	4	8
None	5	10
<b>Total</b>	<b>50</b>	<b>100</b>

**Source: Author 2012**

#### **4.8. Adaptation to Climate Change**

There was no significant difference (Chi-square test = 9.135; DF = 8,  $p < 0.05$  (0.331)) on the level of education reached and definition of the term adaptation. However, 71.4% (n = 10) of respondents from primary level, 21.4% (n = 3) from secondary level and 7.1% (n = 1) from tertiary level termed adaptation as adjustments in ecological, social, or economic systems in response to actual or expected climatic stimuli and their effects or impacts. Those respondents from primary and secondary school levels used their experience to explain the term adaptation and compared with the choices that were provided in the questionnaire.

Adaptation is one of the ways to curb climate change and 77.8 % (n = 7) of respondents from primary level, 22.2% (n = 2) from tertiary level said that adaptation is the process of benefiting from opportunities associated with climate change. 73.3% (n = 11), 13.3% (n = 2) and 13.3% (n = 2) of respondents from primary, secondary and tertiary respectively said that adaptation is a process of getting used to climate change effects and impacts. Of the respondents interviewed, 77.8% (n = 7) from primary, 11.1% (n = 1) from secondary and 11.1% (n = 1) from tertiary said that adaptation is the process to moderate damages of climate change effects. 33.3% (n = 1) of respondents from primary level, 66.7% (n = 2) from tertiary said that adaptation is a process to moderate damages of climate change effects.

#### **4.9 Adaptive outcomes of climate change**

There was no significant association on adaptive outcomes and gender (Chi square test = 3.574; DF = 4;  $p = 0.467$ ). Both men and women were well represented in identifying the adaptive outcomes of climate change. From the Table 4.7 below, 90% (n = 9) of men and

10% (n = 1) women respondents said enhanced collective action as an adaptive outcome of climate change. This is because in case of flooding, the diseases that emerge afterwards affect the community and people come together to help those who are mostly affected. 67% (n = 8) of male and 33% (n = 4) of female respondents interviewed said increased food security. This came about as a result of bumper harvest to store as much food as possible so that they could have sufficient food in dry periods. Of the respondents interviewed, 88% (n = 7) of male and 12% (n = 1) of female talked about increased storage of water as an adaptive outcome. They said their animals at home have been having problems and also their crops during dry season that was why they build reservoirs and tanks for water storage. Of the respondents interviewed, 89% (n = 8) of male and 11% (n = 1) of female said that more health centers developed.

**Table 4.7: Percentage of Adaptive Outcomes and Gender**

Adaptive outcomes	Male		Female		Total	
	N	%	N	%	N	%
Enhanced collective action	9	90	1	10	10	<b>100</b>
Increased food security	8	67	4	33	12	<b>100</b>
Increased storage of water	7	88	1	12	8	<b>100</b>
More health centers developed	8	89	1	11	9	<b>100</b>
Increased tree cover	10	90	1	11	11	<b>100</b>
<b>Total</b>	<b>42</b>		<b>8</b>		<b>50</b>	

**Source: Author 2012**

This came about due to aftermath of floods where certain water borne diseases develop and they do not have health centers where they can be treated. 90% (n = 10) of male and 10% (n = 1) of female respondents said that there was increased tree cover. This was due to reforestation through forestry programmes in marginalized areas, range lands, on farm tree planting to enhance carbon sinks. Apart from what respondents said about adaptive outcomes, a sustainable management forest resource is encouraged to enhance ecosystems.

This implies that if the community members adapt to outcomes of climate change, they would not experience problems compared to communities that do not adapt.

#### **4.10 Strategies of Adaptation Practices to Climate Change**

Communities living around Kakamega have experienced many forms of extreme climate events. Over time, they have developed a range of adaptive responses to cope with

environmental risks to their livelihoods. Such responses safeguard livelihoods, and thus have a strong economic orientation. Table 4.8 below shows how local adaptation responses to climate variability have been classified into five broad categories in Kakamega Forest.

**Table 4.8: Distribution of Different Strategies of Adaptation Practices to Climate Change.**

<b>Strategies of Combating/ Adapting to climate change</b>	<b>Frequency</b>	<b>Percentage (%)</b>
Mobility	6	12
Storage	5	10
Diversification	22	44
Communal Pooling	8	16
Exchange	9	18
<b>Total</b>	<b>50</b>	<b>100</b>

**Source: Author 2012**

#### **4.10.1 Mobility**

According to table 4.8 above, 12% of the respondents denote movements of the household as a local institution and how they respond to risks and scarcities. The pattern of movement in the local and research institutions helps us to understand why certain things are happening within the society such as development projects, wage labor migration, involuntary migration and remittances (joint with exchange). Particularly, the dependence on forest resource is exuberated on how the other institutions behave.

Most women stay home to care for children, as well as the sick or elderly family members while men can migrate to access economic opportunities (Patt, *et al.*, 2009). Their ability to migrate in search of economic opportunities makes it easier for men to deal with crisis, and may result in benefits for the family as a whole. However, male migration often increases women’s workload, as they are left behind to manage the household in addition to usual tasks. It can also increase women’s exposure to other risks, such as gender-based violence and HIV infection (Patt, *et al.*, 2009)

#### **4.10.2 Storage**

Storage of past surpluses of food is an effective measure against future livelihood failures. In Kakamega forest, 10% of the respondents said that agricultural households surpass the

“professional household” having created indigenous storage infrastructure for seeds and harvested crops and have developed time-tested procedures for drying cereals and grains for storage. Most women are responsible for storage and preparation of food while men are responsible for selling valuable produce and livestock.

In addition to the challenges described above, climate change has implications for food preparation and storage (in terms of water for food preparation and the vulnerability of food stores to extreme events, such as cyclones and floods). Harvests may be reduced or even wiped out by floods or droughts. This affects market prices and the availability of surplus to sell – placing pressure on both men and women to identify other sources of income and reduce major expenditures (e.g. school fees). In times of food shortage, women are often expected to feed other members of the family before attending to their own needs (UNDP, 1996).

Appropriate technologies for water harvesting are available and supported for the household and community. Better integration of planning for water and agricultural development is also practiced. This has also been practiced by research institutions such as gene bank for preservation of genetic materials. Institutions also have water harvesting being mainstreamed into agricultural extension, targeted public investment for community and public water infrastructure.

#### **4.10.3 Diversification**

Of the respondents interviewed, 44% said local institutions in Kakamega have decreased and thus the need to introduce other modern means of adapting to climate change. This occurs in relation to, on and off farm employment opportunities, productive and non-productive assets and consumption strategies. Fields in areas where rainfall is unreliable and the local farmers have embarked on different farm management practices and crop cultivators, and use of combination of occupations such as wage labour and small scale animal rearing less farm. This has a great impact on the management of the forest since the dependency is mainly on other resources ok than the forest.

#### **4.10.4 Communal Pooling**

Communal pooling has been used around Kakamega to mainly reflect on their values, norms and traditions as said by 16% of the respondents interviewed. Although they do not have joint ownership (communalism) and sharing of wealth, labour, or incomes across households, or mobilization of resources held collectively during times of scarcity, they assist each other in occasions such as weddings, burials and fund raisings.

#### **4.10.5 Market Exchange**

This is perhaps the most versatile mechanism used for adaptation to climate change impacts in Kakamega forest. However, 18% of the respondents said that there are well-developed markets, exchange instruments and widespread access. Although they are fully practiced nationally, survival of the local institutions has been pegged towards barter and bi-lateral links to assist their populations.

### **4.11 Climate Change knowledge and Gender**

There was no significant differences (Chi square Test=3.586; DF =3; p=0.310) on male and female and what they know about climate change. This indicated that gender was well used in disseminating climate change information. The respondents were asked one question about knowledge of climate change but they gave different answers.

Table 4.9 below shows that, male 83% (n = 10) and female 17% (n = 2) respondents interviewed said that climate change are variations in the earth's weather, including changes in temperature, wind patterns and rainfall.

Male respondents (n = 10) represented by 100% said that climate change is change in average weather conditions or the distribution of weather around the average conditions. When this question was asked no female respondents knew climate change by this definition as most of them did not complete primary and secondary education and did not have access to climate change information and other conservation strategy information. 86% (n = 12) of male and 14% (n = 2) of female respondents interviewed said that climate change is increase of temperature of earth's atmosphere that is caused by increase in gases especially carbon dioxide. However, 71% (n = 10) of male and 29% (n = 4) of female

respondents said that climate change is significant and lasting change in the statistical distribution of weather patterns over periods ranging from decades to millions of years.

**Table 4.9: Climate Change and Gender**

Definition of climate change	Male		Female		Total	
	N	%	N	%	N	%
i. Changes in the earth's weather, including changes in temperature, wind patterns and rainfall	10	83	2	17	12	<b>100</b>
ii. Change in average weather conditions or the distribution of weather around the average conditions.	10	100	0	0	10	<b>100</b>
iii. Increase of temperature of earth's atmosphere that is caused by increase in gases especially carbon dioxide.	12	86	2	14	14	<b>100</b>
iv. Significant and lasting change in the statistical distribution of weather patterns over periods ranging from decades to millions of years.	10	71	4	29	14	<b>100</b>
<b>Total</b>	<b>42</b>		<b>8</b>		<b>50</b>	

**Source: Author 2012**

#### 4.12 Policy and Legislation in Kakamega Forest and Gender

There was no significant difference (Chi square test=4.277; DF =6; p=0.639) on gender and the policies governing Kakamega forest. This indicated that gender aspects were considered well in identifying policies governing Kakamega forest. From the Table 4.10 below, 93% (n = 13) of male and 7% (n = 2) of female said that there were no policies governing Kakamega forest as indicated by (i). However, these are some of the policies named by the respondents interviewed and 80% (n = 4) of male and 20% (n = 1) of female respondents said that for sustainable management of forests, they carry out inventories and valuation of forest resources and their utilization to generate accurate information for decision making labeled as (ii).

Of the respondents interviewed, 83% (n = 5) of male and 16% (n = 1) of female respondents said that they empower local communities to manage forests through community forest associations labeled as (iii). Of the male and female respondents 60% (n = 3) and female 40% (n = 2) respectively, said that they ensure that forest plantations are sustainably managed to realize their maximum potential as indicated by (iv).

**Table 4.10: Policy Governing Kakamega Forest**

Policies	Male		Female		Totals (%)
	N	%	N	%	
i. No policies	13	93	1	17	<b>100</b>
ii. Carry out inventories and valuation of forest resources and their utilization to generate accurate information for decision making.	4	80	1	20	<b>100</b>
iii. Empower local communities to manage forests through community forest associations.	5	83	1	17	<b>100</b>
iv. Ensure that forest plantations are sustainably managed to realize their maximum potential	3	60	2	40	<b>100</b>
v. Promote the sustainable management of forests for climate amelioration, soil, and water and biodiversity conservation.	11	92	1	8	<b>100</b>
vi. Support forest management, which will embrace preservation of religious and cultural sites, traditional medicinal sources, water catchments, and habitats for endemic and threatened species of flora and fauna.	2	67	1	33	<b>100</b>
vii. Support the formulation of criteria and indicators for sustainable forest management.	4	80	1	20	<b>100</b>
<b>Total (N)</b>	<b>42</b>		<b>8</b>		<b>50</b>

**Source: Author 2012**

Table 4.10 above shows that 92% (n = 11) of male and 8% (n = 1) of female respondents said they promote the sustainable management of forests for climate amelioration, soil, water and biodiversity conservation labeled as (v). 67% (n = 2) of male and 33% (n = 1) of female respondents said that they support forest management, which will embrace preservation of religious and cultural sites, traditional medicinal sources, water catchments, and habitats for endemic and threatened species of flora and fauna as indicated by (vi). 80% (n = 4) of male and 20% (n = 1) of female respondents support the formulation of criteria and indicators for sustainable forest management labeled as (vii).

Kenya Forest Service (KFS) is said to be a beneficiary in the new legislation since it has gained the much-needed autonomy in the management of the forests. As a Department in the Ministry of Environment and Natural Resources, forest management was subject to the

slowness and difficulties of bureaucratic decision-making. Revenues generated through the sector are also submitted directly to the treasury.

The Kenya Forest Service on the other hand can make decisions independent of the parent ministry and has the privilege of determining the use of revenues generated from its enterprise. Thus despite a loss of the tight grip that the department held over forests and having to share authority with new actors, the losses are well countered by the gain in control over revenues which can be ploughed back into enhancing the quality and effectiveness of management.

#### 4.13 Mitigation and Gender

There was no significant association (Chi test = 0.683; DF = 1; p = 0.409) on gender and mitigation. Gender was well used in defining mitigation in Kakamega forest.

**Table 4.11: Mitigation and Gender**

Mitigation	Male		Female		Total	
	N	%	N	%	N	%
i. Actions that reduce the rate of change and the extent of change we may see with climate change.	25	81	6	19	31	<b>100</b>
ii. Elimination or reduction levels of frequency magnitude of exposure to risks or minimization of the potential impact of threat or warning.	17	89	2	11	19	<b>100</b>
<b>Total</b>	<b>42</b>		<b>8</b>		<b>50</b>	

**Source: Author 2012**

Table 4.11 below shows that 81% (n = 25) male and 19% (n = 6) female respondents said that mitigation are actions that reduce the rate of change and the extent of change we may see with climate change labeled as (i). 89% (n = 17) of male and 11% (n = 2) of female respondents gave a different meaning of mitigation as elimination or reduction levels of frequency magnitude of exposure to risks or minimization of the potential impact of threat or warning labeled as (ii). In as far as there was no significant association, most of the respondents had a slight knowledge of what mitigation is.

#### 4.14: Mitigation Measures and Level of Education

Mitigation measures have been put in place to curb climate change in many sectors of life. In this study, there was no significant association (Chi test 14.012; DF = 10; p = 0.172) on mitigation measures to curb climate change and the level of education reached by

respondents. From the table 4.12 below, 60% (n = 3) of primary level and 40% (n = 2) of tertiary level respondents interviewed said that they use clean development mechanism as a mitigation measure to curb climate change labeled as (i). This involved carbon trading. 56% (n = 5) of primary level, 33% (n = 3) of secondary level and 11% (n = 1) from tertiary level respondents said that they cut on burning of fossil fuels labeled as (ii).

**Table 4.12: Mitigation Measures and Level of Education**

Mitigation measure	Level of education						Total	
	Primary		Secondary		Tertiary		N	%
	N	%	N	%	N	%		
i. Clean development mechanism (CDM)	3	60	0	0	2	40	5	100
ii. Cut on burning of fossil fuels	5	56	3	33	1	11	9	100
iii. Enhancement of carbon sinks	7	78	1	11	1	11	9	100
iv. Evaluate adaptation through economic analysis	4	67	2	33	0	0	6	100
v. Reduction of Green House Gases (GHGs)	13	87	0	0	2	13	15	100
vi. Monitoring and evaluating adaptation activities	4	67	0	0	2	33	6	100
<b>Total</b>	36		6		8		50	

**Source: Author 2012**

The table 4.12 above shows that 67% (n = 4) from primary level, 33% (n = 2) of secondary level of education said that they evaluate adaptation through economic analysis and monitoring and evaluation adaptation activities as mitigation measure as labeled as (iv) and (vi) respectively. This involved the analysis of extent of how climate change has affected different sectors of economy especially agriculture whereby they would increase food security through bumper harvests.

Moreover, they would increase storage of water through massive water harvesting. Of the respondents interviewed, 78% (n = 7) from primary level, 11% (n = 1) from secondary level and 11% (n = 1) from tertiary level said that they enhance carbon sinks to mitigate climate change labeled as (iii). This involved planting of trees on marginalized land, afforestation exercises, planting trees on range lands and on farm tree planting (agro forestry).

Of the respondents interviewed, 67% (n = 4) from primary level and 33% (n = 2) from tertiary level said that they mitigate through monitoring and evaluating adaptation activities. 87% (n = 13) from primary level and 13% (n = 2) from tertiary level respondents said they mitigate through reduction of Green House Gases from anthropogenic sources labeled as

(v). This involved better farming methods, reduction on burning of fossil fuels for industrial activities, changes in land use including agriculture and deforestation and usage of clean energy.

Greenhouse gasses would be reduced through biological carbon sequestration and whereby more plants would be planted and as growth takes place, they use carbon dioxide from the atmosphere for photosynthesis and also store more carbon in their lifetime through the process of greenhouse gas sink. Carbon dioxide is exchanged between atmosphere and plants and soils on land as former cropland or remains after harvests is converted into grassland as new areas are cultivated to become cropland. There is need to introduce clean energy technologies and clean development mechanisms to mitigate climate change for example solar, wind and water of which they produce little or no greenhouse gasses once in operation if any at all.

#### 4.15: Rules and Forest Governance

There was no significant association on the rules controlled by KWS, and KFS and gender of respondents (Chi Test = 1.416; DF = 4; p = 0.841).

**Table 4.13: Rules that Govern Kakamega Forest**

Rules REGARDING:	Enforcement Agency	Gender				Total %	
		Male		Female		N	%
		N	%	N	%		
i. Infrastructure changes in the forest (roads, Bridges, ditches)	KFS&KWS	9	90	1	10	10	<b>100</b>
ii. Type of seedlings planted in the forest	KFS	4	80	1	20	5	<b>100</b>
iii. The number of wild game that could be trapped or killed in order to control degradation of the forest?	KWS	5	71	2	29	7	<b>100</b>
iv. When fires may be or can be started in the forest	KFS	9	82	2	18	11	<b>100</b>
v. Type of seedling in relationship to the product	KFS	15	88	2	12	17	<b>100</b>
<b>Total (Frequency)</b>		<b>42</b>		<b>8</b>		<b>50</b>	

**Source: Author 2012**

From the table 4.13 above, 90% (n = 9) of male and 10% (n = 1) of female respondents interviewed said that infrastructure changes in the forest including roads, ditches and bridges exists labeled as (i). Kenya Forest Service and Kenya Wildlife Service enforce infrastructure changes in the forest involving roads, bridges and ditches.

Most of the residents do not use the roads and bridges to access forest resources instead they use other routes which destroy the flora and fauna. This has effect on climate change because the products, which are young and not meant for harvesting, are harvested together with the mature ones hence leading to depletion, which in turn affects the water towers, and carbon sinks. There is no regeneration as this exercise is repeated more often and this causes global warming hence climate change.

Of the respondents interviewed, 88% (n = 15) of male and 12% (n = 2) of female said that they knew of the type of seedling planted in the forest labeled as (ii). The type of seedlings planted in the forest is enforced or controlled by Kenya Forest Service. Some of the seedlings issued by the relevant body are not the proper seeds for a given environment.

The conditions they are subjected to are not the best for them and hence they end up doing badly or not germinating at all. Others are good in type and especially *Antiaristoxicaria*, *Ficussur*, *Polysciasfulva* which are well distributed and they mature faster providing carbon sinks and this is evidenced by 80% (n = 4) of male and 20% (n = 1) of female respondents interviewed where they said that there is a rule on the type of seedling in relation to the product.

The rule on the amount of wild game that could be trapped or killed in order to control degradation of the forest controlled by the custodian as labeled (iii) was acknowledged by 71% (n = 5) of male and 29% (n = 2) of female respondents interviewed. Kenya Wildlife Service controls the number of wild game that could be trapped or killed in order to control degradation of the forest. This has to some extent been problematic according to respondents because there are a very big number of wild animals compared to the pasture available and due to climate change impact and especially drought, which affects the pasture regeneration and growth, the animals, tend to consume other important plant species that are good for carbon sequestration.

According to table above, 82% (n = 9) of male and 18% (n = 2) of female respondents interviewed said that when the forest fires may be or can be started in the forest existed labeled as (iv). Kenya Forest Service knows when and where the forest fires may be or can be started. This helps in minimizing the population of plant species in the forest to avoid competition for nutrients and also prevent soil degradation. However, some fires are as a result of catastrophes and they affect the growth and development of plants which leaves the

soil bare subjecting it to soil erosion and degradation and due to this there is no top soil left to store carbon. This results to increased amount of carbon in the atmosphere leading to global warming and climate change.

Kakamega Forest was gazetted as a National reserve in 1985 and governed by the central government. The Kenya Forest Service and the Kenya Wildlife Service work to protect the forest. Rules adherence has always been a challenge in developing countries. Characterized by low per capita income and lack of employments, the livelihood of forest adjacent communities is mainly on the natural resources. Moreover, the study area was not exceptional with previous studies showing that the region is one of the most densely-populated rural areas in the world, and pressure on the Forest resources is considerable.

#### **4.16. Activities the Kenya Forest Service Co-ordinate seasonally**

According to the Table 4.14 below, 16% (n = 8) of the respondents said that they plant seedlings in the forest every month. These seedlings mature from nursery after two to three months and transplanted to the field in order to replace cut trees. 12% (n = 6) of the respondents harvest products from the forest which include honey, fuel, wild fruits, tree barks, timber and non – timber products among others. These products are usually consumed in the households are sold to earn a living and improve the standard of living. 14% (n = 7) of the respondents say that the products are distributed among them by the CBO leaders and other products are sold to the local community and major towns and cities in the country.

Of the respondents interviewed, 8% (n = 4) said that there is a season set aside for harvesting of forest products. People do not go to harvest any product and this is evidenced by 16% (n = 8) of respondents saying that they have to be ready enough to be harvested and also must be of quality and the type of technology used to harvest forest product is good and has been helping them especially to increase their harvest. 12% (n = 6) of the respondents said that there are people who are authorized to harvest forest products because they have the knowledge of the technology used. This helps in reduction in destruction of branches, leaves, flowers and buds.

Some of forest products are important and sacred and 4% (n = 2) of the respondents said that they use them for religious purposes like grapes among others. 10% (n = 5) of the

respondents say that they maintain the forest through clearing along the roads inside the forest and along the fenced areas.

**Table 4.14: Activities the Kenya Forest Service has coordinated**

<b>Activities done seasonally</b>	<b>Frequency</b>	<b>Percentage (%)</b>
Planting seedlings	8	16
Harvested forest products	6	12
Distributed and sold forest products to local users	7	14
Season when to harvest the forest product	4	8
Quantity of forest products harvested and technology used	8	16
Authorized personnel to harvest forest products	6	12
Uses of forest products (including religious uses)	2	4
Rented non-transferrable rights to harvest forest products and other maintenance	5	10
Monitored forest condition and compliance to rules	4	8
<b>Total</b>	<b>50</b>	<b>100</b>

**Source: Author 2012**

This helps local and international tourists, forest guards and local community to have better access to the forest. They rented other people non-transferrable rights to harvest forest products. This happens if people assigned responsibility of harvesting are not enough for harvesting a particular product. 8% (n = 4) of the respondents said that they monitor forest condition on monthly basis. They monitor if there are dead fallen trees that need to be removed, those that need pruning, if tree barks have been removed and the community complies with the rules.

#### **4.17. Conflicts**

Conflicts that occur so much within Kakamega community are those associated with the use of resources within Kakamega forest. There is no significant association between conflict existence and level of education attained by the respondents (Chi Test = 1.895; DF = 2; p =

0.388). There are minimal cases of existence of conflicts within the communities and 73% (n = 35) respondents from primary level and 12% (n = 6) from secondary education and 15% (n = 7) from tertiary level of education say there are no conflicts existing between the custodian and other organizations. However, 50% (n = 1) from primary and tertiary levels of education said there exist conflicts between the custodian and other organizations as shown by Table 4.15 below.

**Table 4.15: Conflicts within Kakamega Forest and the Level of Education**

Conflict existence	Level of education of respondents						Total (%)	
	Primary		Secondary		Tertiary		N	%
	N	%	N	%	N	%		
Yes	1	50	0	0	1	50	2	<b>100</b>
No	35	73	6	12	7	15	48	<b>100</b>
<b>Total</b>	<b>36</b>		<b>6</b>		<b>8</b>		<b>50</b>	

**Source: Author 2012**

The conflicts addressed by 50% (n = 1) of the respondents are those associated with the adherence and compliance of rules and regulations that govern the forest. The respondents having higher level of education are conversant with the conflicts that affect community and forest use than those having lower level of education especially those who attained primary level.

There have been conflicts in management of forest between the Kenya Forest Service, Kenya Wildlife Service and Community Forest Associations. This is mostly shown through their differences who should be the custodian in governing a certain resource within the forest. Kenya Forest Service is responsible for plants in the forest while Kenya Wildlife Service is responsible for wildlife and Community Forest Associations are responsible for small activities such as harvesting of forest products, maintaining roads among others. Most of the associations are supposed to report to either KFS or KWS.

These conflicts experienced were misappropriation of funds, competition for meagre resources, leadership wrangles, conflicting interests, and lack of commitment by members or leaders. Most of these conflicts were occasioned by the fact that the officials were unwilling to vacate the positions upon completion of their terms or when not re-elected; these were also the people who misappropriated group funds. The lack of commitment by members was mainly due to the lack of or little benefits accruing to them leading to disillusionment.

#### 4.18: Mechanisms for Conflict Resolution

Various mechanisms have been used to resolve conflicts between Kenya Wildlife Service, Kenya Forest Service and Community Forest Associations in Kakamega forest. They include the following: - penalties/fines, suspension, and withdrawal of user rights, court order and excommunication. This study shows that there is no significant association (Chi square test = 1.968; DF = 4; p = 0.742) between mechanisms for conflict resolution and gender of the respondents interviewed.

**Table 4.16: Mechanisms for Conflict Resolution**

Mechanisms	Gender				Total (%)
	Male		Female		
	N	%	N	%	
Court orders	2	67	1	33	<b>100</b>
Excommunication	5	100	0	0	<b>100</b>
Penalties and fines	13	87	2	13	<b>100</b>
Suspension	7	78	2	22	<b>100</b>
User rights withdrawn	15	83	3	17	<b>100</b>
<b>Total (Frequency)</b>	<b>42</b>		<b>8</b>		<b>50</b>

**Source: Author 2012**

Table 4.16 above shows that 67% (n = 2) of male respondents and 33% (n = 1) of female respondents interviewed said that those who had serious allegation and could not be solved internally had court orders to resolve their conflicts. These conflicts were associated with misappropriation of forest resource funds.

Of the respondents interviewed, 100 % (n = 11) of male said that members of the organization were excommunicated from the groups for breaking the law. In this case, no female respondent gave response that ant member was communicated for breaking the law. It is also shown that, 87% (n = 13) of male and 13% (n = 2) of female respondents interviewed said that penalties or fines were given to the law offenders on competition on usage of the resources in Kakamega forest.

About 78% (n = 7) of male and 22% (n = 2) of female respondents said that most of the members of the organizations were suspended from their duties due to conflicting interests between them. 83% (n = 15) of male and 17% (n = 3) of female respondents said that rights were withdrawn to the organization members who deferred the rule and regulations that govern use of resources in Kakamega forest as shown in the table below. These conflicts

were as a result of lack of commitment for their responsibilities by the CFA members and leaders.

#### 4.19: Conflict Resolution and Gender

Conflicts have been resolved using various methods in Kakamega Forest. The methods include negotiations, peace building, arbitration, accommodation, mediation and conciliation. The distribution of male and female was significantly associated (chi square test = 14.864; DF = 5; p = 0.011) with conflict resolution within Kakamega forest. 100% (n = 10) of male respondents interviewed said that conflicts involving the members of the organization and community members are resolved using accommodation whereby they call a meeting for all members who in this case help in deciding on the most appropriate course of action.

Table 4.17 above indicates that 83% (n = 5) of male and 17% (n = 1) of female respondents interviewed said that some conflicts could be solved using conciliation method whereby majority decision or a consensus is reached. 100% (n = 5) of male respondents interviewed said that conflicts involving the management of forest resources are solved using arbitration whereby chairmen and executive council of various organizations are involved. 44% (n = 4) of male and 56% (n = 5) of female respondents interviewed said that some conflicts involving internal issues within the organization are solved through mediation.

**Table 4.17: Conflict Solutions**

Conflict Resolution	Gender				Total
	Male		Female		
	N	%	N	%	
Accommodation	10	100	0	0	<b>100</b>
Arbitration	5	100	0	0	<b>100</b>
Conciliation	5	83	1	17	<b>100</b>
Mediation	4	44	5	56	<b>100</b>
Negotiation	10	83	2	17	<b>100</b>
Peace Building	8	100	0	0	<b>100</b>
<b>Total</b>	<b>42</b>		<b>8</b>		<b>50</b>

**Source: Author 2012**

This involved EOs (Environmental Officers) who talk to the members of organization on how best they could conserve the environment and implement policies without conflicts. 83% (n = 10) of male and 17% (n = 2) of female respondents said that conflicts are solved through negotiation whereby small issues such as decision making are addressed at local

level through the forest area committee, a smaller body of the executive committee of the association. 100 % (n = 8) of male respondents said that conflicts are solved using peace building method whereby meetings are held with the board members who discuss and resolve the problems.

## **CHAPTER FIVE: CONCLUSIONS AND RECOMMENDATIONS**

### **5.1 Introduction**

In an attempt to find out how institutions worked together towards mitigating climatic change through decentralization of forest resources in Kakamega forest in Kakamega County, face to face interviews were conducted using structured questionnaire to the respondents and direct observations were made. Data gathered were analyzed. Based on the findings, conclusions were drawn and recommendations were made on suitable management strategies. Areas of further research were also suggested which could complement the study.

### **5.2 Conclusions**

Local-based informal institutions are central in combating climate change impacts, especially with external interventions. A combination of governmental and research institutions enhance local communities adaptation strategies by providing proven techniques and expertise and this add value to particularly, diversification and communal pooling adaptation used by local communities.

Despite the critical importance of local institutions in shaping adaptive responses to climate change, existing work on research and policy regulations, focuses primarily on technological, infrastructure, embankments, dams, flood proof buildings, and provision of new crops as alternative options.

Government institutions facilitate adaptation strategies related to communal pooling and diversification, and their ability to channel technical and financial inputs into rural areas enhances adaptation to changing climatic scenarios.

However, despite the efforts by government, research and local institutions, a number of institutional obstacles such as social resistance to change, weak governance, ineffective institutional arrangements and lack of information on key vulnerability indicators remain a challenge.

### **5.3 Recommendations**

Based on the respondents' experience, the following recommendations were suggested in order to mitigate climate change through decentralization of forest resources.

1. A greater role for institutional partnerships in facilitating adaptation to climate change is needed. Support for such partnerships would greatly enhance sustainability of informal institutions and enhance their capabilities to adopt.
2. Before providing resources and external support, the role of local institutions and their linkages must be understood. Vulnerable groups in general have lower institutional access than do those who are more powerful or better off. Before external support for greater adaptive capacity is made available, an analysis of the nature of institutional linkages and access for different social groups is critical.
3. Institutional coordination across scales, for better planning and implementation must be improved.
4. An adaptive perspective on institutional development must be adopted. Because the state of knowledge is sparse about the most effective ways in which institutions can facilitate local adaptation, no blueprints can be advanced for planning adaptive development. The development of greater adaptive capacity will require a willingness to experiment, tolerate mistakes, and promote social learning and behavioral change in terms of increasing risk management.

### **5.4 Suggestions for Further Research**

Future research that could add value to the problem of climate change in our society and globally could focus on, among others, the following themes:

1. More research should be carried out to establish ways the government can implement measures on protection of forest through conservation institutions.
2. A study targeting female headed households in the study area to have a better comparison between the performances of technologies under various households' headships.

3. Similar studies should be carried out on ways to link institutions to be under one umbrella and have the same policies governing the use of resources to avoid conflicts.
4. Further research should be done on introduction of new technologies to help community members on how well they can benefit from forest products without depleting the forest.

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## APPENDICES

### APPENDIX A: QUESTIONNAIRE A

*Tick ✓ where necessary on the box provided.*

#### BIOGRAPHIC DATA

Date: \_\_\_\_\_/\_\_\_\_\_/2011

Questionnaire number \_\_\_\_\_

1. Sex of respondent: Female  Male
2. Age of the respondent

#### EDUCATION

3. Please mark the **highest** level of education reached by respondent:
  - i. Primary
  - ii. Secondary
  - iii. Tertiary
  - iv. Other specify
4. What language is spoken here?
5. Are there other languages spoken? Name them
6. What is the climatic condition of Kakamega region?
  - a. Cool and wet
  - b. Hot and dry
  - c. Cool and dry
  - d. Hot and wet
7. For the past 10 years, what do you think is the status of Kakamega forest?
  - Decreasing
  - Increasing
  - No change

8. What do you think are the reasons for 7 above?
  
9. What is adaptation?
  
10. What are adaptive measures?
  
11. Name the adaptive outcomes of climate change.
  
12. What do you understand by the term climate change?
  
13. Are the policies influencing outcomes in adapting to climate change?
  
14. What do you understand by the term mitigation?
  
15. What are the mitigation measures put in place to curb climate change in Kakamega forest and its environs?
  
16. How often do you go inside the forest?
  - a. Daily
  - b. Weekly
  - c. Monthly
  - d. others (Specify)

17. Are you aware of any existing rules and regulations that govern the forest?

a. Yes

b. No

If yes, which ones?

18. Are these rules adhered to?

a. Yes

b. No

19. Who is the custodian?

a. Central government

b. Communal ownership

#### **POLICY LEGISLATION INFORMATION**

20. Are you aware of policies governing the Kakamega forest?

21. For how many years has this organization had its present structure? (in years)

22. How many years has this organization been involved in the governing of this forest? (in years)

23. Where is the organizational office located in relationship to the forest? (Kilometers)

24. Do other organization(s) interact within Kakamega forest?

a. Yes

b. No

If yes, name them

25. Have there been any major changes in governance of the forest?

- a. Yes
- b. No

If yes, name them. If no give reasons

26. What activities has this organization(s) coordinated?

27. In your opinion, do you think there exist any conflicts between the rules created by custodian and other organization(s)

- a. Yes
- b. No

If yes, please describe them

28. Are any mechanisms available to resolve conflicts?

- a. Yes
- b. No

If yes, name them.

29. How do internal conflicts in the organization get resolved?

30. Give suggestions on ways of sustaining a balance in the management of Kakamega forest amongst all stakeholders?

## QUESTIONNAIRE B

*Tick ✓ where necessary on the box provided.*

Date: \_\_\_\_\_/\_\_\_\_\_/2011

Questionnaire number \_\_\_\_\_

1. For the past 10 years, what do you think is the status of Kakamega forest?
  - Decreasing
  - Increasing
  - No change
2. What do you think are the reasons for 1 above?
3. Are you aware of any existing rules and regulations that govern the forest?
  - a. Yes
  - b. No

If yes, which ones?

4. Are these rules adhered to?
  - a. Yes
  - b. No

## POLICY LEGISLATION INFORMATION

5. Are there any policies that influence utilization of Kakamega forest in:
  - a. Landuse
  - b. Agricultural
  - c. Wildlife
  - d. Forest conservation

If yes, list them.

6. What are some of the mitigation measure your institution has put in place to curb climate change in:

- a. Land use
- b. Agricultural
- c. Wildlife
- d. Forest conservation

Name them?

7. Are there any policies influencing the outcomes in adapting to climate change?

a. Yes

\_\_\_\_\_ in a positive way

\_\_\_\_\_ in a negative way

\_\_\_\_\_ both

b. No

If yes, name them

8. Which organization brought the changes or is most influential in forest conservation and management?

9. In your opinion, do you think there exist any conflicts between the rules created by custodian and other organization(s)

c. Yes

d. No

If yes, please describe them

10. Are any mechanisms available to resolve conflicts?

c. Yes

d. No

If yes, name them.

11. How do internal conflicts in the organization get resolved?

12. What is decentralization of forest resources?

13. Does decentralization of forest resources benefit this forest?

a. Yes

b. No

If yes, name the benefits

**APPENDIX B: Plot Location**

<b>Plot ID</b>	<b>Longitude</b>	<b>Latitude</b>
1	34.87534064190	0.31790293775
2	34.88733312540	0.29239511577
3	34.84888103550	0.30838509373
4	34.85706638140	0.28877833504
5	34.86449029970	0.27221728644
6	34.83136820250	0.26288979930
7	34.81613965210	0.28420976991
8	34.94824732710	0.34283968909
9	34.93339949050	0.31961614968
10	34.95281589230	0.30648152492
11	34.90884345290	0.28744583688
12	34.88828490980	0.27069443140
13	34.89651289560	0.23280732076
14	34.92945098880	0.23130708933
15	34.95440575290	0.24441604476
16	34.98983497550	0.24999426279
17	34.97219574560	0.27411628668
18	34.94424260320	0.27104140582
19	34.92334864720	0.25316027842
20	34.90751856900	0.21999249557
21	34.98847811170	0.21893715703
22	34.94324931690	0.21381122695
23	34.97732167560	0.19496589578
24	34.95546109150	0.18124649469
25	34.95304888910	0.15441074311
26	34.90163882570	0.18968920306
27	34.93239440610	0.18803081391
28	34.88460264630	0.17114539719
29	34.90254340160	0.14883252509
30	34.91324754970	0.12983643127