IMPACT OF CLIMATE CHANGEAND APPLICATION OF ECOSYSTEM BASED ADAPTATION IN KAKAMEGA FOREST, KENYA

BY

JOHN AYIEKO ASETA

A RESEARCH THESIS SUBMITTED IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF DEGREE OF DOCTOR OF PHILOSOPHY IN GEOGRAPHY

DEPARTMENT OF GEOGRAPHY AND ENVIRONMENTAL STUDIES,

SCHOOL OF ARTS AND SOCIAL SCIENCES

MOI UNIVERSITY

2021

DECLARATION

Declaration by the Candidate

This Thesis is my original work and has not been presented for a degree in any other University. No part of this Thesis may be reproduced without the prior written permission of the author and/ or Moi University.

Sign: ________________________________ Date:______________________________

JOHN AYIEKO ASETA
SASS/DPHIL/GEO/02/2018

Declaration by Supervisors

This Thesis has been submitted for examination with our approval as University Supervisors.

Sign: ________________________________ Date: ______________________________

Prof. Paul Omondi
Department of Geography and Environmental Studies,
Moi University, Eldoret, Kenya

Sign: ________________________________ Date: ______________________________

Dr. Abdirizak A. Nunow
Department of Geography and Environmental Studies,
Moi University, Eldoret, Kenya

DEDICATION

This Thesis is dedicated to my parents Mr. Sabastian Aseta Ngwacho and Mrs. Keresensia Aseta in gratitude.

ACKNOWLEDGEMENT

My sincere gratitude and appreciation goes to all those who made the completion of my work a reality. I am especially thankful to my supervisors Prof. Paul Omondi and Dr. Abdirizak A. Nunow for their insightful guidance and advice.

I would like to express my sincere appreciation to the members of staff in the Department of Geography and Environmental Studies, and the School of Arts and Social Sciences at large for their fruitful suggestions and valuable contributions towards this work. To my lecturers, under whom I took various courses, thank you for laying a firm foundation that culminated to a successful work. I thank all colleagues particularly the 2017 PhD Geography class for moral support and encouragement.

To all my family members, and friends who provided encouragement and support of whatever kind, thank you. My brothers and sisters were tirelessly of help in many ways and I appreciate. I also thank Mr. Adrian Oboiko for neat typing of the thesis.

Finally, I acknowledge all my respondents that included local people and forest officers of Kakamega County who willingly gave information to the study.

The author would like to absolve all individuals and institutions mentioned above for any errors of omission and/or commission or any interpretational error(s). For these, the author remains solely responsible.

ABSTRACT

Climate change has direct impacts on forest ecosystems, like changes in productivity, functional trait composition and species extinction or range redistribution. These changes have been associated with increased drought stress, drying or dieback. Climate change can also have indirect impacts on forest ecosystems, for example, increased fire frequency .Worldwide and regional climate simulations for the next few decades project changes in precipitation and warming that may seriously impact major biomes all over the world. The general objective of this study was to assess the impact of climate change on forest ecosystems in Kenya with special emphasis to the application of Ecosystem-based Adaptation to climate change in Kakamega Tropical Rainforest Ecosystem. The specific objectives were: to establish the spatial and temporal characteristics of climate change in Kakamega Tropical Rainforest ecosystem, to analyze ecosystem services of Kakamega Tropical Rainforest, o assess the impact of climate change on Kakamega Tropical Rainforest Ecosystem, to evaluate Ecosystem-based adaptation (EbA) initiatives to climate change in Kakamega Tropical Rainforest ecosystem and to establish challenges and constraints facing implementation of EbA initiatives in Kakamega Tropical Rainforest ecosystem. This study was descriptive and cross-sectional in design and relied on a mixed methods approach. Anthropogenic Global Warming Theory and Adaptive Management Theory were used to guide the study. The study also utilized a conceptual framework showing the interrelationship between the independent (climate change) and dependent variables (forest ecosystem). The study utilized both primary and secondary data. The target population was 20,000 households living up to 10km from the forest edge in the selected communities neighbouring Kakamega Tropical Rainforest and 53 government officials within Kakamega County. A total of 184 members of the households were selected using stratified random sampling design and 20 forest officers were purposively sampled as respondents in the study. The study findings revealed that the spatial and temporal characteristics of climate change was very extreme temperatures and precipitation (the results revealed that temperature is increasing by 0.04°C per annum while rainfall amounts have dropped by 150mm for the past fifty three years that is since 1967 to 2020 in the region), the forest ecosystem was also a source of many services to the surrounding community, it also had a great impact on the surrounding community. Several challenges to the forest ecosystem existed such as high population growth rate, uncertainties around future climate change, deforestation, poverty, economic reasons like fluctuation of markets as some of the constraints or challenges facing the implementation of EbA initiatives. The study recommends that there is need for afforestation and conservation of the forest to get rid of extreme temperatures and precipitation since it is a source of many services to the surrounding communities and that the forest ecosystem helps to adapt or mitigate climate change among others. The study suggest for a further research in other forest ecosystems in Kenya on the effects of forest destruction on the socio-economic conditions of the neighbouring communities.

TABLE OF CONTENTS

DECLARATION ii
DEDICATION iii
ACKNOWLEDGEMENT iv
ABSTRACT v
TABLE OF CONTENTS vi
LIST OF TABLES ix
LIST OF FIGURES x
LIST OF PLATES xii
ACRONYMS AND ABBREVIATIONS xiii
OPERATIONAL DEFINITION OF TERMS xiv
CHAPTER ONE 1
INTRODUCTION 1
1.1 Background to the Study 1
1.2 Statement of the Problem 9
1.3 Objectives of the Study 10
1.4 Research Questions 11
1.5 Significance of the Study 11
1.6 Scope of the Study 12
1.7 Limitations of the Study 13
1.8 Assumptions of the Study 13
CHAPTER TWO 15
LITERATURE REVIEW 15
2.1 Introduction 15
2.2 Spatial and Temporal Characteristics of Climate Change 15
2.3 Ecosystem Services of Kakamega Tropical Rainforest 22
2.4 Impacts of climate change on Kakamega Tropical Rainforest Ecosystem 34
2.5 Ecosystem-based Adaptation to Climate Change in Kakamega Tropical Rainforest 38
2.6 Challenges and Constraints Facing Implementation of EbA Initiatives in Kakamega Tropical Rainforest 52
2.7 Theoretical Framework 55
2.7.1 Anthropogenic Global Warming Theory 56

2.7.2 Adaptive Management Model 58
2.8 Conceptual Framework 60
CHAPTER THREE 61
RESEARCH METHODOLOGY 61
3.1 Introduction 61
3.2 Research Design 61
3.3 Research Philosophy 62
3.4 Study Area 62
3.5 Study Population 66
3.6 Sample Size and Sampling Procedures 66
3.7 Data Collection Instruments 67
3.7.1 Questionnaire 68
3.7.2 Interviews 68
3.8 Piloting 70
3.9 Validity and Reliability of Research Instruments 72
3.9.1 Validity 73
3.9.2 Reliability of the Research Instrument 73
3.10 Data Collection Procedures 74
3.11 Data Analysis 74
3.12 Ethical Considerations 75
CHAPTER FOUR 76
DATA ANALYSIS, RESULTS AND DISCUSSIONS 76
4.0 Introduction 76
4.1 Background Information of Members of Households and Forest Officers 76
4.1.1 Background Information on Forest Officers 81
4.2 Spatial and Temporal Characteristics of Climate Change in Kakamega Tropical Rainforest 82
4.2.1 Mean monthly rainfall variability. 82
4.2.2 Mean annual rainfall variability. 83
4.2.3 Mean monthly temperature variability 84
4.2.4 Mean annual temperature variability 84
4.2.5 Perceptions of climate variability 85
4.3 Ecosystem Services of Kakamega Tropical Rainforest. 93
4.4 Impacts of Climate Change on Kakamega Tropical Rainforest Ecosystem 101

4.5 Ecosystem-Based Adaptation to Climate Change in Kakamega Tropical Rainforest 106
4.6 Challenges and Constraints Facing Implementation of EbA Initiatives in Kakamega Tropical Rainforest 111
CHAPTER FIVE 119
SUMMARY, CONCLUSIONS AND RECOMMENDATIONS 119
5.0 Introduction 119
5.1 Summary of Study Findings 119
5.1.1 Spatial and Temporal Characteristics of Climate Change 119
5.1.2 Ecosystem Services of Kakamega Tropical Rainforest. 120
5.1.3 Impacts of Climate Change on Kakamega Tropical Rainforest Ecosystem 122
5.1.4 Ecosystem-Based Adaptation to Climate Change in Kakamega Tropical Rainforest 123
5.1.5 Challenges and Constraints Facing Implementation of EbA Initiatives in Kakamega Tropical Rainforest Ecosystem 124
5.2 Conclusions 126
5.3 Recommendations 127
5.4 Suggestions for Further Research 128
REFERENCES 129
APPENDICES 147
Appendix I: Questionnaire for Heads of Households 147
Appendix II: Interview Schedule for Government Officials (Kenya Forest Service Officers) 152
Appendix III: Krejcie and Morgan Table 157
Appendix IV: Research Authorization 158

LIST OF TABLES

Table 3.1: Sampling Frame 67
Table 4.1: Background information of members of the households 77
Table 4.2: Spatial and Temporal Characteristics of Climate Change in Kakamega Tropical Rainforest 87
Table 4.3: Ecosystem Services of Kakamega Tropical Rainforest. 94
Table 4.4: Impacts of Climate Change on Kakamega Tropical ..... RainforestEcosystem 102
Table 4.5: Ecosystem-based Adaptation to Climate Change in Kakamega Tropical Rainforest 106
Table 4.6: Challenges and Constraints Facing Implementation of EbA Initiatives in Kakamega Tropical Rainforest 112

LIST OF FIGURES

Figure 2.1: Projected global average surface temperature change over 2006 to 2100 relative to 1986-2005 (Adapted from (IPCC, 2014b), page 11) 21
Figure 2.2: Projected global average surface temperature (a) and rainfall change (b) Adapted from (IPCC, 2014) 22
Figure 2.3: Conceptual Framework 60
Figure 4.1: Locations 78
Figure 4.2: Gender 78
Figure 4.3: Educational Levels 79
Figure 4.4: Occupation..................80
Figure 4.5: Monthly Income 80
Figure 4.6: Years of Stay 81
Figure 4.7: Climate Change as Extreme Temperatures 88
Figure 4.8: Climate Change as Extreme Precipitation..................88
Figure 4.9: Climate Change as Very Extreme Temperature and Precipitation..................89
Figure 4.10: Ever Witnessed Climate Change..................90
Figure 4.11: Climate Change as the Shift of the Rainy and Dry Seasons 91
Figure 4.12: Climate Change as Drought 91
Figure 4.13: Climate Change as Intense Rainfall 92
Figure 4.14: Climate Change as Less Rainfall..................93
Figure 4.15: Forest Ecosystem as a Source of Timber 95
Figure 4.16: Forest Ecosystem as a Source of Herbal Medicine 97
Figure 4.17: Forest Ecosystem as a Source of Fodder for Animals..................97
Figure 4.18: Forest Ecosystem as a Source of Firewood..................98
Figure 4.19: Forest Ecosystem as a Source of Food..................98
Figure 4.20: Forest Ecosystem Service as Prevention of Storms 99
Figure 4.21: Forest Ecosystem Service as Control of Floods..................99
Figure 4.22: Forest Ecosystem Service as Cloud Formation..................100
Figure 4.23: Forest Ecosystem as Greenhouse Gas Regulation 101
Figure 4.24: Changes in Productivity 103
Figure 4.25: Functional Trait Composition 103
Figure 4.26: Species Extinction or Range Redistribution..................104
Figure 4.27: Increased Fire Frequency 105

Figure 4.28 Changes in Precipitation and Warming 105
Figure 4.29: EbA as Measures which use Ecosystem Services to Attain or Support Adaptation to Climate Change 107
Figure 4.30: Policy and Behavioural Changes as EbA Initiative 108
Figure 4.31: Targeted Management as EbA Initiative 108
Figure 4.32: Conservation Activities as EbA Initiative 109
Figure 4.33: Restoration of Highly Degraded Dry Forest as EbA Activity 110
Figure 4.34: Reduction of Biodiversity Loss as EbA Activity Implemented 110
Figure 4.35: If Forest Ecosystem Helped to Adapt or Mitigate Climate Change 111
Figure 4.36: Continued Uncertainities around Future Climate Change as a Challenge towards Implementation of EbA Initiatives 113
Figure 4.37: Higher Population Growth Rate as a Constraint to EbA Initiative Implementation 113
Figure 4.38: Deforestation as a Challenge to Implementation of EbA Initiatives 114
Figure 4.39: Poverty as a Challenge towards Implementation of EbA Initiatives 115
Figure 4.40: Economic Reasons like Fluctuation of the Markets as a Challenge to the Implementation of EbA Initiatives 116
Figure 4.41: Physical Reasons like Remoteness as a Challenge to the Implementation of EbA Initiatives 116
Figure 4.42: Socio-Political Reasons as a Challenge towards the Implementation of EbA Initiatives 117
Figure 4.43: Advice to the Government 118

LIST OF PLATES

Plate 2.3: The Kakamega Tropical Rainforest is a magnificent habitat for biodiversity 31
Plate 2.4: The damage of forest canopies in the Kakamega Tropical Rainforest 32
Plate 3.1: Map of Kakamega Tropical Rainforest Ecosystem and its Environments ..65
Plate 3.2: Researcher with a resource person at the Grassland section of Isecheno at Kakamega Tropical Rainforest Ecosystem 71
Plate 3.3: Kenya Forest Service Western Conservancy 72
Plate 4.1: Demonstration of a plant that serves as a herbal medicine. 89

ACRONYMS AND ABBREVIATIONS

COP	Conference of Parties
DGVM	Dynamic Global Vegetation Model
EbA	Ecosystem-based Adaptation
Eco-DRR	Ecosystem based Disaster Risk Reduction
ES	Ecosystem Services
GCM	General Circulation Model
GHGs	Greenhouse gases
IPCC	International Panel on Climate Change
IUFRO	International Union of Forest Research Organizations
KFEMP	Kakamega Forest Ecosystem Management Plan
MAPSS	Mapped Atmosphere Plant Soil System
NPP	Net Primary Productivity
NRM	Natural Resource Management
REDD	Reduced Emissions from Deforestation and forest Degradation
SSA	Sub-Saharan Africa
TLA	Total Leaf Area
UNFCCC	United Nations Framework Convention on Climate Change
WWF	Worldwide Fund for Nature

OPERATIONAL DEFINITION OF TERMS

Abiotic conditions: (or factors or drivers): environmental variables such as climate, soil conditions, and light availability.

Adaptation: Is the adjustment in human or natural systems in response to expected or actual climatic stimuli or their effects that harm, exploit or moderate beneficial opportunities.

Biomass: is the total amount of live and inert organic matter above and below ground expressed in tons of dry matter per unit area.

Biomass dynamics: the fluxes in biomass per unit area per unit time. Examples of positive fluxes (i.e. biomass increase) are: aboveground biomass increase, tree growth, seedling recruitment, or litter production. An example of a negative flux is tree mortality.

Biomass stocks: the amount of biomass per unit area. This can be based on aboveground living biomass, (fine) root biomass, or soil organic matter.

Biotic conditions (or factors or drivers): attributes of the vegetation, such as taxonomic diversity, trait diversity, community-mean trait values, and/or structural attributes.

Carbon dynamics: fluxes in carbon (in vegetation or soil) per unit area per unit time. Carbon dynamics are sometimes used to replace biomass dynamics because they are very strongly related (biomass is about twice the mass of carbon).

Carbon stocks: the amount of carbon (in vegetation or soil) per unit area. Carbon stocks are sometimes used to replace biomass stocks because they are very strongly related.

Climate Change: Climate change refers to the variation in the earth‘s global climate or in regional climates over time scales ranging from decades to millions of years.

Ecosystem-based Adaptation is the use of biodiversity and ecosystem services aspart of an overall adaptation strategy to help people to adapt to the adverse effects of climate change

Ecosystem functioning: the combined effect of all ecosystem processes that are needed to sustain an ecosystem (Reiss et al. 2009).

Ecosystem functions: often used as a synonym for 'ecosystem processes'. this study 'ecosystem functions' mainly refer to processes that provide benefits to the planet and humans, such as carbon sequestration.

Ecosystem processes: ecosystem-level fluxes or stocks of carbon, water and nutrients, such as biomass stocks or productivity of the whole community.

Ecosystem Services: "Ecosystem services are the direct and indirect benefits that people obtain from nature." These services are classified as provisioning services, regulating services, cultural services and supporting services (Renaud, Sudmeier- Rieux, & Estrella, 2013).

Greenhouse gases This include carbon dioxide, methane, nitrous oxide, and other gases that modify the heat retention capacity of the Earth's atmosphere

Impacts Refers to the positive and negative effects of climate change on forest ecosystem

Kyoto Protocol: An international agreement adopted in December 1997 in Kyoto, Japan. The Protocol sets binding emission targets for countries to reduce their carbon emissions.

Sequestration The removal of carbon from the atmosphere. It is the process of increasing the carbon content of a carbon reservoir other than the atmosphere. Biological approaches to sequestration include direct removal of carbon dioxide from the atmosphere through land-use change, afforestation, reforestation, and practices that enhance carbon in agriculture. Physical approaches include separation and disposal of carbon dioxide from fuel gases or from fossil fuels.

Vulnerability: “The characteristics and circumstances of a community, system or asset that makes it susceptible to the damaging effects of a hazard. Moreover, there are many aspects of vulnerability, arising from various physical, social, economic, and environmental factors” (UNISDR, 2009).

CHAPTER ONE

INTRODUCTION

1.1 Background to the Study

According to Leeuwen, *et al.,* (2011) Climate change has become a global phenomenon with overwhelming evidence. Globally there is a substantial problem in relation to greenhouse gas emissions. The 2013 Physical Science Basis report of the IPCC revealed that concentrations of the greenhouse gases: methane (CH_4), nitrous oxide (N_2O) and carbon dioxide (CO_2)exceeded the highest concentrations recorded in ice cores during the past 800,000 years (IPCC, 2013).

The increase in average concentration in the atmosphere is 150% for CH_4, 20% for N_2O and 40% for CO_2 compared to pre-industrial times in 1750 (IPCC, 2013). More other sources of great importance are emissions from land degradation and deforestation. The concentrations that the planet as a system has been used to over long periods of time are being altered, which has now led to a severe disturbance of radiative forcing. So far, it seems that humans are not able to successfully control the output of emissions to help significantly minimize climate change (Leeuwen *et al*., 2011).

In sub-Saharan Africa (SSA), climate change projections manifest a warming trend with changes in precipitation patterns (Serdeczny *et al.,* 2015). The severity of climatic events is increasingly becoming a challenge not only to humanity but also to the existing natural systems (Intergovernmental Panel on Climate Change (IPCC), 2012).Currently, millions of people across SSA depend on forest products and services for their daily income and well-being. However, not all incomes of forest-based communities are obtained from forest products alone.

In recent years, Kenya's forests have been depleted at an alarming rate with the current forest cover estimated at 7.4 per cent of total land area, which is below the recommended global minimum of 10 per cent (FAO, 2010). The low forest cover in the country is largely attributed to deforestation, induced by excessive human activities, such as illegal logging, unsustainable charcoal production and clearing of forests for farming and settlement (Ongong'a and Sweta, 2014), resulting in forest fragmentation. Kakamega Forest, the only tropical rainforest in Kenya, is no exception as nearly half of it has been lost in the past 38 years due to human activity, leaving only about 230 km^2 of it standing (KFEMP, 2012). While the Government of Kenya (GOK) has made enormous efforts to protect this forest from human interference, it is difficult to save it from the impact of climate change.

Looking at climate change scenarios at the present and future is relevant: "*In recent decades, changes in climate have caused a lot of impacts on natural and human systems on all continents and across the oceans."* (IPCC, 2014). The effect of climate change is experienced comprehensively and most strongly by natural systems, and while human systems are affected in a similar fashion, such is not to the same extent as the natural counterpart (IPCC, 2014). However, the global burden of human beings becoming ill from climate change is relatively small compared to other stressors and is not well quantified. Increased heat-related mortality as well as decreased cold-related mortality has been observed in some regions (From 1998, more than 166 000 people died due to heat waves, including more than 70 000 who died during the 2003 heat wave in Europe) and in some cases local changes in temperature and rainfall have altered the distribution of water borne illnesses (IPCC, 2014).

This understanding is particularly important in the case of triple win interventions that combine anti-poverty, climate resilience and sustainable development actions (Denton *et al.*, 2014) such as Ecosystem-based Adaptation (EbA). Through restoration, management and conservation of ecosystem services and biodiversity, scholars and policy-makers, increasingly believe that many of the problems at the intersection of climate change and poverty can be addressed (Secretary of Convention on Biological Diversity, 2009).

To date, most of the academic work on Ecosystem-based Adaptation (EbA) has concentrated on explaining the possible advantages of ecosystems for adjustment to climate change (Munang *et al.*, 2013) or analyzing the information base for the utilization of ecosystems for adaptation (Brink *et al.*, 2016). Research studies were carried out on EbA at the local level with regards to both developing (Bourne *et al.*, 2016) and developed countries (Geneletti and Zardo, 2016). Different researches have examined the development of EbA in global legitimate systems on climate change and biodiversity (Chong, 2014) and in global climate policy (Ojea, 2015).

The interest and acceptance in adaptation to climate change has gained prominence especially over the last fifteen years (Naumann *et al.*, 2011). In its Fourth Assessment Report, the IPCC proposes to put a higher spotlight on adaptation to expand the capacity of regions, countries, social groups and communities to adapt to climate change in a manner synergistic to sustainable development (Adger *et al.*, 2007). The expanded acknowledgment of the significance of adaptation is additionally reflected in an expanded number of scientific publications. A survey by Glick *et al.*, (2011) found a five-fold increase in climate change adaptation literature from 2007 to 2010 (Glick *et al.*, 2011).

The conservation, management and restoration of ecosystems have been recognized by many specialists as a key component for climate change adaptation and disaster risk reduction (Estrella and Saalismaa, 2013). From this thought the ideas of Ecosystem-based Adaptation (EbA) and Ecosystem based Disaster Risk Reduction (Eco-DRR) have emerged.

In the ensuing years, the idea propelled by this thought called 'Ecosystem based Management' rose in significance and stood out not least because of the publication of the Millennium Ecosystem Assessment in 2005 (Gohler *et al.,* 2013). In the appraisal, the decline of worldwide ecosystem wellbeing was elaborately reported (Mercer *et al,* 2012). In turn, this inspired the conceptualization of the Ecosystem-based Adaptation idea within NGO's and intergovernmental organization circles, as it has been supported by the idea of ecosystem services. It was seen as a methodology of utilizing natural solutions to alleviate climate change (Gohler *et al*., 2013).

Since then, the idea developed as a significant connection between the three Rio Conventions – the United Nations Convention to Combat Desertification (UNCCD) (1997), the Convention on Biological Diversity (CBD) (1993) and the United Nations Framework Convention on Climate Change (UNFCCC) (1992). Out of these three conventions, the CBD is most concerned with the idea. The primary presentation of the idea into the UNFCCC occurred at the Conference of the Parties (COP) 14 out of 2008 in Poland/Poznan, where this issue was pushed by NGO's, for example, the TNC and the IUCN among others (Gohler *et al*., 2013).

For instance, in the African continent the Nairobi declaration by the African Ministers of Environment and Natural Resources on the African Process for Combating Climate Change clearly points out that ‘support for Africa under future climate regime should be based on priorities determined by Africa, which include financing, capacity building, research, technology, adaptation and transfer of knowledge, in particular indigenous knowledge' (World Bank 2009).

A forest as defined by Global Forest Resources Assessment (FRA, 2010) is an area with tree crown cover of more than 10 per cent of the ground and area of more than 0.5 hectares with trees higher than 5 meters. Many scholars and institutions have worked extensively on the mitigation potentials of forest with much focus on the 'clean development mechanisms (CDM)' and 'reducing emissions from deforestation and forest degradation (REDD)'. The UNFCCC also focused on deforestation, reforestation, afforestation, and forest management under the development of rules of the Kyoto Protocol. One major development under UNFCCC was the publication of guidelines for reporting greenhouse gas emissions by sources and removals by sinks resulting from land use, land-use change and forestry (LULUCF).However, many methodological and governance challenges still remain (Mayers, 2009). An overall framework, 'agriculture, forestry and other land uses (AFOLU),' is also being proposed at the UNFCCC as another credible mitigation activity across landscape.

One of the few global views on forest and climate change adaptation options was presented by Seppala *et al.,* (2009).Forestry and forests provide diverse resources, which are depended upon by the respective society for adaptation actions and earning livelihoods. Most of these resources go beyond the protective functions of forest, notably the use of diverse Non Timber Forest Products as 'safety nets'. Livelihoods in Sub-Saharan Africa are so dependent on forest and other natural resources, and climate change adaptation is such a huge priority both at the livelihood and political levels.

Change of climate, combined with, human encroachment, over-exploitation and pollution, are increasingly changing and degrading ecosystems and their ability to deliver the services that are important to human lives and wellbeing (World Bank, 2014). If conserved and well-managed, however, these ecosystems can help enhance the resilience of people to both climatic and non-climatic threats, while providing multiple benefits to both environment and the society (Colls *et al.*, 2009). Based on this backdrop, there is growing recognition that ecosystem-based approaches to climate adaptation can constitute a vital element of a country's strategy for adapting to climate change.

In the year 2010, the Cancun Adaptation Framework of the United Nations Framework Convention on Climate Change (UNFCCC) at its 16th COP invited Parties to enhance action on adaptation by "building resilience of socio-ecological systems, including through economic diversification and sustainable management of natural resources"(UNFCCC 2011). At the centre of the concept of Ecosystem- based Adaptation is the importance of seeing beyond the role of ecosystems as providers of a set of static 'natural resources' and instead seeing them as generators of a number of interconnected ecosystem services (Reid and Alam, 2014).

Same as human beings, ecosystems are more resilient to stressors and better able to adapt to adverse conditions when they are healthy and fully functioning. MEA defines resilience as the capacity of a system to tolerate impacts of drivers without irreversible change in its outputs or structure. Ecosystems have limits, however, beyond which they cannot function in their current form. When these limits are breached, an ecosystem may no longer be able to provide the services on which humans have come to depend on (Scheufele and Bennett, 2012). What sets Ecosystem-based Adaptation apart from business as usual ecosystem management and conservation, is that EbA uses nature-based approaches to help people adapt to the current and future impacts of climate change. The CBD EbA definition emphasizes that this is not merely a by-product, but the end goal of EbA (Martin, 2011).

Tropical forests cover about 10% of the Earth surface, but store 25% of global terrestrial carbon and account for 34% of terrestrial gross primary productivity (Malhi, 2012). They therefore feature prominently in climate change mitigation policies, such as Reduced Emissions from Deforestation and forest Degradation (REDD). In these forests, the 2% largest stems account for at least 27% of the aboveground biomass (Slik *et al.*, 2013).

The continent of Central America is a biodiversity hotspot area, and the region's governments have demonstrated their commitment to biodiversity conservation through the Mesoamerican Biological Corridor (Holland 2012). However, future climate change can alter the distribution and composition of species and ecosystems (Imbach *et al.*,2013), leading to a need for conservation strategies to be reassessed. Projections of the possible impacts of climate change on ecosystems can help support assessments of conservation needs and adaptation measures in the region.

In April 2009,the International Union of Forest Research Organizations (IUFRO) published the global assessment report on the "Adaptation of Forests and People to Climate Change" (Seppala *et al.*, 2009). That report presents the state of information regarding the impacts of climate change on forests, the socio-economic implications and the options for adaptation. However, given the global scope of the assessment and the limited time available, it was not possible to systematically analyze and compile information for particular geographical regions.

Ecosystem-based Adaptation often overlaps with other socio-economic goals such as sustainable development and poverty alleviation (Munang *et al.*, 2014). In China, poverty highly overlaps with ecologically vulnerable areas that are sensitive to climate change (Oxfam 2009). Comparatively, Kakamega Tropical Rainforest area, although high in biodiversity, is one of the most ecologically vulnerable areas in Kenya.

Added to the low adaptive capacities of rural populations, climate change impacts on forests will exacerbate the vulnerability of any forest-dependent community (Okali, 2011). Past studies conducted in Kakamega County have identified and emphasized the impacts of climate change on smallholding farmers (Barasa *et al*., 2015; Ochenje *et al.,* 2016; Mulinya, 2017). However, little is known and documented on climate variability and related impacts on the Kakamega Forest Ecosystem.

Most climate change studies have either ignored or devalued climate variability, probably due to uncertainties with regard to expected future changes in rainfall and temperature variability (Ramirez-Villegas et al., 2013; Thornton et al., 2014). For this reason, the impact of climate variability on forest ecosystems are still poorly understood (Turpie and Visser, 2013). Understanding climate variability trends is critical in mitigating adverse effects on the forest ecosystems. Against this backdrop, this study sought to determine the impact of a changing climate and the application of EbA on the Kakamega tropical rainforest ecosystem. The findings would not only enrich our understanding of climate variability and its related impacts on forest ecosystems but also provide insights to researchers and policymakers on practical initiatives needed to enhance resilience at the local scale.

The focus of this study was on forest Ecosystem-based Adaptation (EbA) approaches to climate change because of their relative novelty. As an emerging field of practice, EbA is more likely to be shaped by actors who aim to promote innovations, that is, by entrepreneurs. EbA has been defined in several ways (Milman and Jagannathan, 2017). Furthermore, there are even less studies illustrating and measuring the co-benefits of EbA although there are numerous studies showing the contribution of forest ecosystem to poverty alleviation, and how adaptation helps with poverty (Martin *et al.*, 2010, Tanner & Mitchell 2008). This study used Kakamega Tropical Rainforest ecosystem to provide quantified social economic evidence of how Ecosystem-based Adaptation (EbA) overlaps poverty alleviation through the lenses of fulfillment of basic needs and subjective well-being.

In view of this, the study focused on impact of climate change and the application of Ecosystem based Adaptation to climate change in Kakamega Tropical Rainforest ecosystem.

1.2 Statement of the Problem

Globally, forests cover approximately 42 million km^2 of land, which is approximately 30% of the Earth's land surface, supplying a variety of valuable ecosystem services such as climate regulation, water regulation, habitat provision, provision for foods, medicines, and aesthetic values (Nkem et al., 2010). However, ecosystem services provided by forests are becoming scarcer in many countries, especially in the tropics (Carrasco and Papworth, 2014; Mutoko *et al.*, 2015). Tropical forests are the single most important terrestrial biome with a capacity to provide multiple ecosystem services, although tropical forests only cover approximately 6% of the global land surface (Saatchi *et al.*, 2011).

The rate of decline of ecosystem services supply from the world's tropical forests is also higher than other forest biomes (Liu *et al.*, 2015). Therefore, understanding the dynamics and nature of ecosystem services supplied from a tropical forested landscape is paramount to ensure their future conservation and recognition of their importance to humanity. The main reasons for this decline are climate change, forest degradation, land use and land cover change and, most importantly, the reduced focus on the sustainable management of ecosystem services. Ecosystem services management in natural resource management planning is not well addressed due to the lack of scientific information on the nature and distribution of ecosystem services, poor understanding of the supply of ecosystem services processes and unknown trends of ecosystem services under future climate change scenarios.

A key focus for EbA was, therefore be on enhancing ecosystem resilience by maintaining ecosystem structure and functioning in response to current and future impacts. More concretely, this involves securing the stability and resilience of ecosystems as a whole; how they connect with one another; and the multiple roles they can play in increasing the adaptive capacity and resilience of people depending on these ecosystems (Epple and Dunning 2014).

It was on this basis that this study critically examined the impact of Climate Change on forest ecosystems in Kenya with special emphasis to the application of Ecosystem based Adaptation to Climate Change in Kakamega Tropical Rainforest ecosystem.

1.3 Objectives of the Study

The general objective of this study was to assess the impact of Climate Change on forest ecosystems in Kenya with special emphasis on application of Ecosystem based Adaptation to Climate Change in Kakamega Tropical Rainforest ecosystem.

The specific objectives were:

1. To establish the spatial and temporal characteristics of climate change in Kakamega Tropical Rainforest ecosystem.
2. To analyze ecosystem services of Kakamega Tropical Rainforest.
3. To assess the impacts of climate change on Kakamega Tropical Rainforest Ecosystem.
4. To evaluate Ecosystem-based Adaptation approaches to climate change in Kakamega Tropical Rainforest ecosystem.
5. To establish challenges and constraints facing implementation of Ecosystem Based Adaptation initiatives in Kakamega Tropical Rainforest ecosystem.

1.4 Research Questions

This study was guided by the following research questions:

1. What are the spatial and temporal characteristics of climate change in Kakamega Tropical Rainforest ecosystem?
2. What are the forest ecosystem services of Kakamega Tropical Rainforest?
3. What are the impacts of climate change on Kakamega Tropical Rainforest ecosystem?
4. Evaluate Ecosystem-based Adaptation approaches to climate change in Kakamega Tropical Rainforest ecosystem.
5. What are the challenges and constraints facing implementation of EbA initiatives in Kakamega Tropical Rainforest Ecosystem?

1.5 Significance of the Study

There are very few studies on the role of forests in mitigating climate change, especially in Kenya. This study provides a crucial step in efforts aimed at assessing and understanding the role Kakamega Tropical Rainforest would play in mitigating climate change in Kenya.

Neither the impacts and institutional response of climate change with regard to forests, nor the role forests play in a society's adaptation are well understood by many decision makers and development actors: especially in the context of the Sub-Saharan Africa. Therefore, more research may improve the understanding of these issues.

One approach to conserve the forest is to examine the potential economic value of the forest to sequester carbon, disseminate this knowledge and involve local communities and other stakeholders to realize this benefit.

The study was 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 would 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.

1.6 Scope of the Study

This study was carried out in Kakamega Tropical Rainforest Ecosystem which is located in Kakamega County of Kenya. The study area was purposively selected as it is one of the Tropical Rainforest in Kenya rich in biodiversity and also because of the recognized vital role it plays in the ecosystem.

The study focused on the spatial and temporal characteristics of climate change, ecosystem services, the impacts of climate change, ecosystem based adaptation approaches and the challenges and constraints facing implementation of EbA initiatives in Kakamega tropical rainforest Ecosystem.

1.7 Limitations of the Study

This study collected data from Kakamega Tropical Rain Forest Ecosystem of Kakamega County, the findings can only be true to the area, and lack of generalizations was therefore a major weakness of this study. However, similar studies can be conducted in other areas. The research design which was descriptive in nature may not give all the required information; other studies should be conducted in other areas using different research designs to ascertain the existence of the same problem.

Unavoidable errors from respondents and those arising from sampling design may have affected the precision of the results. In real world situation and experience in the economic phenomena, most variables may be interrelated in one way or another which may not be easily understood or captured.

1.8 Assumptions of the Study

The following were the basic assumptions of the study:-

1. There existed spatial and temporal characteristics of climate change in Kakamega Tropical Rainforest ecosystem.
2. There existed ecosystem services of Kakamega Tropical Rainforest.
3. There were potential impacts of climate change on Kakamega Tropical Rainforest ecosystem.

4. There existed Ecosystem-based Adaptation measures to climate change in Kakamega Tropical Rainforest ecosystem.
5. There were challenges and constraints facing implementation of EbA initiatives in Kakamega Tropical Rainforest ecosystem.

CHAPTER TWO

LITERATURE REVIEW

2.1 Introduction

This chapter focuses on the review of various studies conducted and recorded in journal articles, paper presentations in conferences, books, web- articles and other sources. The review is organized into five sections based on the objectives of the study. The review also covers theoretical considerations and conceptual framework for the study.

2.2 Spatial and Temporal Characteristics of Climate Change

Past studies have demonstrated how forested areas and their surroundings have experienced general reductions in precipitation and increases in temperature over time (Boon and Ahenkan, 2011). These changes profoundly affect the overall health of the ecosystem, reducing the supply of forest materials such as foods, fuelwood, medicinal herbs and other non-timber forest products (NTFPs). In due course, this will impose additional stress on the forest ecosystem.

Changes in temperature have been extensively studied and are well understood across a wide range of temporal and spatial scales. The Fifth Assessment Report from the Intergovernmental Panel on Climate Change Working Group I illustrated that the globally averaged land surface air temperature has risen since the 19thcenturyby an average increase of 0.72 degrees Celsius from 1951 to 2012, with the greatest amount of warming occurring since the 1970's (IPCC, 2013). However, trends in precipitation, globally and regionally, are less obvious. Precipitation in the tropics (30 degrees N to 30 degrees S latitude) has both decreased and increased since the 1970's; precipitation has increased in the last decade(2000's), reversing the drying trend observed from the 1970's to late 1990's (IPCC, 2013).

The annual UNEP Emission Gap Report compares the current track of emissions that we are on, to what is required to keep global warming to a maximum of a 2°C average increase in temperature compared to pre-industrial times with a likelihood of more than 66%. It shows that we are falling behind (UNEP, 2013). The 2°C maximum increase in temperature is a debate on its own and shall not be examined at this point in detail, as it is a political ‘goal’ that has been agreed upon in the Copenhagen Agreement in 2009 at the Conference of Parties 15 and is heavily debated. Many argue that a 2°C rise in temperature is already way beyond a temperature in which adverse climate change effects are out of control (Olson *et al*. 2014).

At smaller spatial scales minimum temperature on the island of Oahu in Hawaii, USA have an average increase of 0.17 degrees Celsius per decade (Safeeq *et al*.,2013) and the statewide average warming for Hawaii is 0.2 degrees Celsius per decade since 1975 (Giambelluca *et al*.,2008).The complexity of precipitation trends is even greater when comparing changes at smaller spatial scales, as significant differences in annual precipitation trends have been observed across three islands in the Hawaiian Archipelago (Chenand Chu, 2014). The island of Hawaii itself has seen a predominately positive annual precipitation trend, as well as precipitation intensity, though most of the increase is located in the high elevations surrounding Mt. Mauna Loa. Opposite trends, with decreasing precipitation intensity are seen on the much drier, western side of the island (Chu et al., 2010). These localized and regional spatial patterns of precipitation dictate water resources on the island scale, with regions of highest precipitation home the highest resource availability (Hawaii County Water Use and Development Plan, 2010).

Therefore, patterns then play a large role in resource management, especially in tropical island settings where freshwater resources quickly meet the ocean (Falkland, 1999). Changes in precipitation patterns lead to concerns for water resource management as extreme events, such as droughts and floods, will likely occur more frequently and with a higher severity in the future (Brekke *et al*., 2009). In Hawaii in particular, declines in base flow and low-stream flow have been noted across the entire Hawaiian Archipelago (Bassiouini and Oki, 2013); though only surface water records were used, the decline in flow indicate a long-term decrease in water resources availability statewide, including Kona where only minimal surface water is available (Hawaii County Plan, 2010).

The interaction between climatic elements, vegetation attributes and ocean surface temperature variations are not properly explained and there are contrasts from area to another throughout the world. As per numerous past studies, the climate parameters and the Normalized Difference Vegetation Index (NDVI) have a positive connection on geographical position, geomorphology, vegetation type, climatic condition and other factors (Zhong *et al.*, 2010).

Vegetation condition is dependent on soil type, moisture of soil and type of vegetation in the area; in addition, climatic elements, for example, temperature, precipitation and ocean surface temperature. Among those numerous elements of vegetation dynamics, the climatic elements are very unpredictable and variable in a very short period of time, spatially and temporally (Zhong *et al.*, 2010). Precipitation varies more in both space and time than other climatic elements. All other factor of vegetation dynamics are most likely dependent of climatic elements and they don't vary temporally in a very short period of time like temperature and precipitation. This spatiotemporal variation of climatic factors has great influence on the vegetation dynamics and seasonal farming productivities (Nicholson *et al*., 1990).

Because of overexploitation through enormous lawful and unlawful logging between the years 1960s and 1990s, the forest flora is dominated by a mixture of large secondary-growth trees and hardly any primary-growth trees. Even for this secondary forest, much of the closed canopy and contiguity exists only in the northern part of the forest, consisting of the Buyangu blocks, which are now protected as a national wildlife reserve. The southern end, involving the Ikuywa, Yala and Isecheno just as the isolates units of the Malava, Kisere, and Kaimosi blocks, are managed as forest reserves but are still accessible to the local public community despite some level of official restriction (Bennun *et al.*, 1999).

In Ethiopia, Gojam area, most of the population depends on rainfall-based agriculture and agricultural related activities for their livelihoods. These days, the occasional rainfall is not coming on time and is reducing in amount (UNFCCC, 2010). Precipitation variance has noteworthy long and short term impacts on natural resources especially wetlands, rivers, forests and lakes. The economy of the Gojam populace is mainly based on rain-fed agriculture. Regardless of the availability of surface and groundwater resources, the failure of seasonal rains seriously affects the area's agricultural activities that lead to food insecurity and other hardships.

The World Meteorological Organization (WMO, 2011) states that, climate variability represents variations in the mean state and other statistics, (for example, standard deviations, the occurrence of extremes, and so on.) of the climate on all temporal and spatial scales beyond that of individual weather events. The term is regularly used to indicate deviations of climatic statistics over a given timeframe (for instance a season, year or month) from the long-term statistics relating to the corresponding calendar period. Variations might be because of natural internal processes within the climate system (internal variability), or to variations in natural or anthropogenic external forcing (external variability).

In the smaller spatial scales, the vegetation index is partly associated with root depth, vegetation types and soil properties. In addition, little is known quantitatively, with respect to the degree to which spatial variation of the vegetation index relies upon rainfall seasonality in tropical rainforest at regional scale (Barbosa and Lakshmi Kumar, 2011). Geo-statistically based spatial and temporal analyzes of NDVI and other related climatic parameters would be useful to understand how they would be related to each other in the zone and to make predictions of a parameter based on the signal of another one.

The factors or driving forces can be classified as human and natural induced. In the study area, the natural driving forces factor might be generally geological or meteorological phenomena like earthquake, resembles climate change, soil type, steep relief, tremor, and extreme precipitation. Population pressure, immense agricultural and deforestation, as well as plough of grass or bush land caused by the population increase are also human factors. In the last few decades, conversion of grasslands, forest and woodland into cropland and pasture has risen significantly in the tropics (Shiferaw, 2011). A significant increase in cultivated land instead of forestland was found to have occurred between 1957 and 1995 in Gojam (Shiferaw, 2011). The most significant changes were, destruction of the natural vegetation, expansion of grazing land and increased farms.

Climate is explained in terms of the variability of relevant atmospheric variables, such as, wind, humidity, snowfall, temperature, clouds, precipitation including extreme or occasional ones, over a long period of time in a specific area. The classical period for performing the statistics used to define climate corresponds to at least 3 decades or 30 years, and it is designated by “climate normal period”, as defined by the World Meteorological Organization (WMO). As a consequence, the 30-year period proposed by the WMO should be considered more as an indicator than a norm that must be followed in all cases. This meaning of the climate as representative of conditions over several decades should, of course, not mask the fact that climate can change rapidly.

Climate can thus be viewed as a synthesis or aggregate of weather in a particular area and for a long time (Goosse *et al.*, 2010). This involves the region's general pattern of weather conditions, seasons and weather extremes like droughts, rainyor hurricanes periods. Two of the most significant variables determining an area's climate are precipitation and air temperature (Goosse *et al*., 2010).

There is need to also consider the fact that the state of the atmosphere used in defining the climate given above is influenced by numerous processes involving not only the atmosphere but also the vegetation, the sea ice, the ocean, etc. Climate is thus now more and more frequently defined in a wider sense as the statistical description of the climate system (Goosse *et al.*, 2010). This includes the analyses of the behavior of its five major components: cryosphere; solid water, i.e. sea ice, glaciers, ice sheets, etc., biosphere (all the living organisms) , the atmosphere; the gaseous envelope surrounding the Earth, the land surface and the hydrosphere; liquid water, i.e. ocean, lakes, underground water, etc., and the interactions between them (Solomon *et al.*, 2007).

It has also been projected that global mean surface temperatures will increase a further 0.3°C to 1.7°C, 1.1°C to 2.6°C, 1.4°C to 3.1°C, and 2.6°C to 4.8°C by the end of this century (2081-2100), relative to 1986–2005 under RCP (Representative Concentration Pathway) 2.6, RCP4.5, RCP6.0 and RCP8.5 respectively with considerable anomalies in the rainfall (Figures 2.1 and 2.2) (IPCC, 2014). Therefore, it can be hypothesized that climate change will substantially affect the ecosystem services supply in this century.

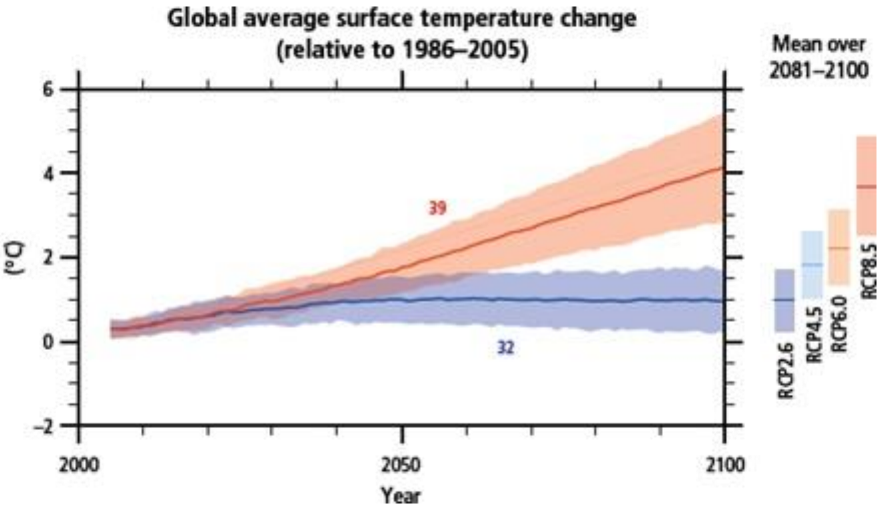

Figure 2.1: Projected global average surface temperature change over 2006 to 2100 relative to 1986-2005 (Adapted from (IPCC, 2014b), page 11)

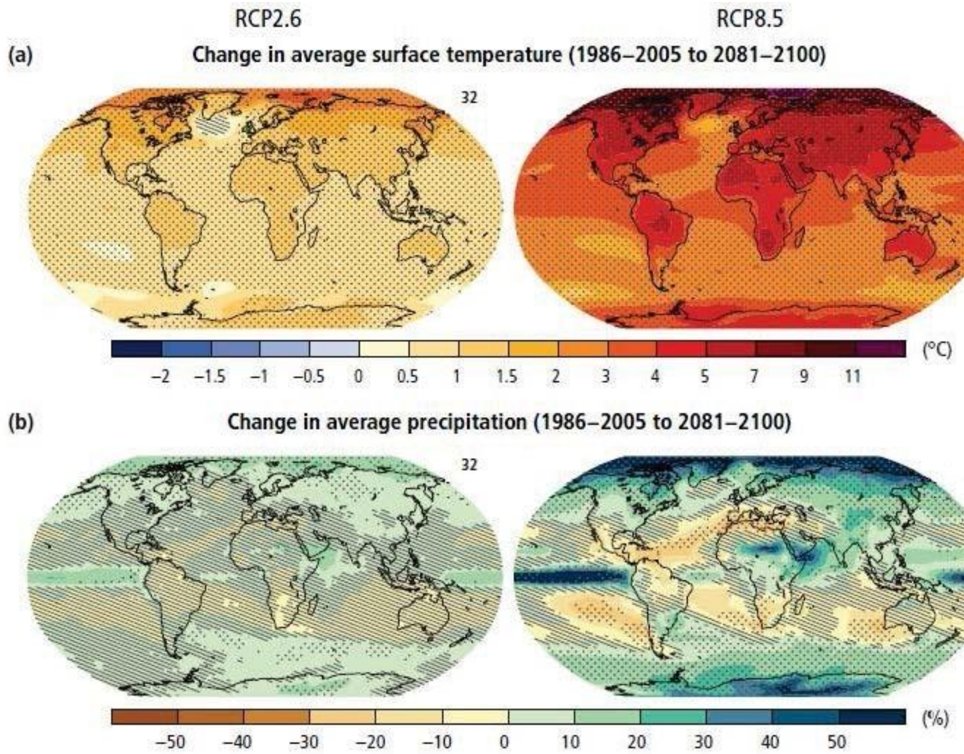

Figure 2.2: Projected global average surface temperature (a) and rainfall change (b) Adapted from (IPCC, 2014)

Tropical forests are thus significant for climate change mitigation, but climate change in turn also influences the temporal dynamics of tropical forests and consequently their mitigation capacity. Spatial variation in a biotic conditions, for example, soil fertility and yearly precipitation highly determines spatial variation in biomass (Malhi, 2012, Poorter *et al.,* 2015), and therefore temporal changes in a biotic conditions can lead to temporal changes in biomass stocks and other ecosystem processes. Moreover, biotic conditions, which are properties of the vegetation itself, for example, species diversity and community weighted mean characteristics, can determine ecosystem processes and in this way the climate mitigation potential of tropical forests.

2.3 Ecosystem Services of Kakamega Tropical Rainforest

The idea of ecosystem services is relatively a new science (Fisher *et al.,* 2009) however developing quickly, particularly after the initiative of Millennium Ecosystem Assessment. The idea of ecosystem service includes both the goods and services that are utilized by human populace. Examples of goods include: production of timber, fuel, fish, crops and fodder; examples of services on the other hand include: storm protection, flood control, cloud formation, and greenhouse gas regulation (Egoh *et al.,* 2010).At the same time, life sustaining goods and services are essentially ecosystem services. To do so, they set the condition of "directly consumed" to be as final ecosystem services. More recently, Fisher *et al.,* (2009) considered all services either directly consumed or indirectly consumed as ecosystem services.

On the same perspective, weather extremes are well-known to have grave impacts on agricultural farming. As rural livelihoods become more precarious, rain-fed agricultural and livestock systems will bear the brunt of climate extremes, adding to the vulnerability of forest-dependent communities who form a significant portion of poor rural farmers (Ofoegbu *et al.,* 2016). Specifically, reduced crop yields compromise food security, affecting the health conditions of vulnerable groups including the elderly, women and children (Altieri and Nicholls, 2017). Moreover, while grazing animals inside forests is a widespread practice among forest-adjacent communities, biodiversity loss means inadequate pastures and this adds more psychological pressures on livestock farmers, who will be forced to look for alternative animal feeds

Ecosystem services research is still in the evolving phase of development across the world. Internationally, researchers have been evaluating various aspects of Ecosystem Services, for example, quantifying and mapping Ecosystem Services (Anderson-Teixeira *et al.,* 2012; Deng *et al.,* 2011; Egoh *et al.*, 2008; Eigenbrod *et al.,* 2010;

Kalacska *et al.,* 2008; Li *et al*., 2011; Naidoo *et al.*, 2008), developing practical frameworks for the appraisal of Ecosystem Services (Posthumus *et al.,* 2010), describing the nature of relationships between Ecosystem Services and biodiversity (Egoh *et al.*, 2009; Egoh *et al.*, 2010) and creating models, (for example, In VEST) and web-based tools, (for example, ARIES) for Ecosystem Services analysis (Johnson *et al.*, 2012; Nelson *et al.*, 2009; Youn *et al.*, 2011).

People benefit in various ways from ecosystems and the services they offer. While it has been the subject of investigation since the mid-twentieth century, the idea itself gained most of its popularity through the work of the Millennium Ecosystem Assessment in 2005 in which 1300 researchers explored the status of the ecosystem services in a momentous work (Fisher, 2008).

The findings of MA’s study was that 15 of the 24 ecosystem services internationally are in decline and that negative impact on human welfare is likely to be expected in the future. The appraisal suggested for heightened research in measuring, modelling and mapping of ecosystem services. By doing so, the 1300 researchers moved the science encompassing the idea significantly forward and stirred the desire for many that this framework would give a new and generous source of conservation financing. It started a great volume of work being conducted in the field (Simpson, 2011). The same scenario has also been reported from the temperate forested landscapes and from forests in California (Shaw *et al*., 2011). It is still unclear about what will be the pattern for tropical forest ecosystem services under future climate change scenarios. Over the period 1880 to 2012, the mean global surface temperature has increased by 0.85°C (IPCC, 2014).

Ecosystem services are at the focal point of the idea of Ecosystem-based Adaptation. Since the publication of two seminal studies about ecosystem services two decades ago various categorization systems were produced for policymaking, scientific analysis, and economic valuation. Four classifications of ecosystem services are now broadly distinguished (Costanza *et al.*, 2017): supporting, regulating, provisioning and cultural services. However, harnessing these services often requires combination of ecological processes with built, human and social capital.

First and foremost, provisioning services, combined with built, human and social capital, produce, for example, timber, fibre and food. Secondly, regulating services, combined with built, human and social capital, produce water regulation, human disease regulation, flood control, storm protection, water purification, pest control, air quality maintenance, climate control and pollination (Costanza *et al*., 2017). Thirdly, cultural services, combined with built, human and social capital, offer cultural identity, recreation, scientific, aesthetic, sense of place, or other ‘cultural’ benefits. Lastly, supporting services describe the basic ecosystem processes such as provisioning of habitat, nutrient cycling, soil formation and primary productivity. They contribute indirectly to human wellbeing by maintaining the processes and functions necessary for provisioning, regulating, and cultural services (Costanza *et al.*, 2017).

Ecosystem services vary with regard to their private or public good attributes that is whether their consumption is excludable and rival. Most provisioning services are ‘private goods’, or can at least be privatized, that is individuals or private enterprises control the means of production and supply chains (Paudyal *et al.*, 2016). On the contrary, most regulating services are ‘public goods’ that is goods that are non-excludable and from which multiple users can simultaneously benefit. Most cultural services consist of a mix of private and public goods (Costanza *et al.*, 2017; Paudyal *et al*., 2016). Some elements of adaptation to climate change are public goods, for example, the conservation of important habitats and common cultural heritage.

The idea of ecosystem services is usually utilized these days to show the connection between the functioning of ecosystems to human prosperity (Fischer *et al.*, 2009). For example, Ecosystem services as the conditions and processes through which natural ecosystems and their constituent species support and satisfy human life; Ecosystem services as the advantages human populace derive, directly or indirectly, from ecosystem functions; Ecosystem services as the benefits individuals get from ecosystems, and Ecosystem service as the ecological components/ items directly consumed or enjoyed to contribute to human prosperity.

Fischer *et al*., (2009) contend that any endeavor at classifying ecosystem services ought to be a function of both ecosystem and ecosystem service attributes. The decision making context for this is determined by the following: benefits from rival and excludable goods, spatial and temporal dynamism of ecosystems and their services, multiple services produced by multiple ecosystems, ecosystem complexity structure, process and service, and benefits dependent upon understanding of ecosystem services.

For the majority, ecosystem services is a promising strategy to look at nature from a more economic point of view – a strategy that would enable pricing of nature. The expectation is that ecosystems and their services would get a different sort of thought in the political field if it would be possible to put a hard monetary number on an ecosystem service. For instance, if it would be possible to assess the value of the water filtration that a certain ecosystem in a region provides were it preserved, this number could potentially be compared to alternative options to purify the water (Chong, 2014).

Supporters of the idea contend this would be a good method of quantifying the value of ecosystems and by doing so, it would give sound economic reasons for conservation. This line of argument is easy to follow and makes a lot of sense at first glance, but what if an assessment reveals that the monetary value of the services of a certain ecosystem is incredibly low, would this automatically mean that this environment is not worth protecting? What about intrinsic values of nature, could they be accounted for? This is one of the core criticisms that the concept receives – it fundamentally adopts a utilitarian, anthropocentric conceptualization of the relationship between ecosystems and human well-being (Chong, 2014).

Technical and ethical constraints are being ascribed to the operationalization of the ecosystem service structure in the processes of decision making (Adams and Redford, 2009). Conservationists articulate the fear that if governments and businesses can be persuaded to mainstream monetary evaluation of ecosystem services, they are likely to do their sums rather quickly. This may lead to a scenario in which diverse ecosystems that produce economic returns will be preserved and those that do not would be either converted or transformed in order to increase returns (Adams and Redford, 2009).

The discussion surrounding the framework highlights the challenges of balancing ecocentric and anthropocentric views regarding biodiversity conservation and ecosystem management(Chong, 2014). The discussion sets aside the framework and has managed to point out the essential services ecosystems provide and received international attention by communities and decision makers – successfully increasing the significance of nature conservation on policy agenda globally (Chong, 2014). In relation to Ecosystem-based Adaptation, Chong (2014) states that:

> ”Ecosystem-based Adaptation, as an extension of the ecosystem services framework, similarly has the potential to inspire efforts to confront the impacts of climate change and acknowledge the importance of nature to supporting societal adaptation” (Chong, 2014).

Majority of the country side households in developing countries and Kenya specifically are predominantly engaged in diverse livelihood strategies and activities. One of these ways is the extraction of forest products and which gives a substantial contribution to their well-being (Babulo *et al*., 2009). Other livelihood ways include trading, livestock husbandry, crop cultivation and unskilled jobs. A livelihood is defined as comprising the capabilities, assets and activities required for a means of living’. Livelihoods are considered to be sustainable when they can cope with and recover from stress and shocks and maintain or enhance their capabilities and assets both now and later on.

In recent years the importance of non-timber forest products (NTFPs) commercialization as a technique to reduce poverty and conserve forests has become prominent (Brown and Lassoie, 2010)as the dependence of poor rural livelihoods on forest income increases. Likewise, Babulo *et al.*, (2009), after sampling 360 rural households in 12 villages in northern Ethiopia, found that income from forest products occupied the second largest share of the mean total household income after crop income. Numerous governments in Africa also value timber production for income generation more than any other forest ecosystem services, whereas livelihoods in many rural communities in Africa depend to a greater extent on NTFPs for subsistence and income generation (Babulo *et al.*, 2009). This is similar with the international pattern for which the highest proportion (30%) of the functions of the world's forests is designated for production of timber and also NTFPs (FRA, 2010).

The human effect on planet Earth is increasing quickly, with regard to both scale and intensity (Steffen *et al.,* 2011, Malhi *et al.,* 2014). One of the significant human-instigated impact is worldwide climate change. To keep climate change within safe limits (Rockstrom *et al.,* 2009), global leaders have been discussing alternatives to mitigate and adapt. A significant step was made during the Conference of the Parties (COP) of the United Nations Framework Convention on Climate Change (UNFCCC), in December 2015 in Paris. Here, 196 nations agreed to lessen greenhouse gas emissions and increase Carbon dioxide removal from the atmosphere, with the ultimate objective to keep worldwide temperatures from rising by more than 2°C (United Nations, 2015). Carbon dioxide removals from the atmosphere are naturally done by growing vegetation, through the process of photosynthesis. Vegetation types that store and remove a lot of Carbon dioxide, for example, tropical forests, are therefore highly relevant for climate change mitigation.

Tropical forests contribute to climate change mitigation in three different ways. In the first place, biomass in tropical forests contains about 25% of all carbon on just about 12% of the region in the terrestrial biosphere, which implies that forestalling deforestation and forest degradation can lessen Carbon dioxide emissions. Second, tropical forests are Carbon dioxide 'sinks', implying that they remove net Carbon dioxide from the atmosphere, and utilize this in photosynthesis to produce additional aboveground and belowground biomass (Brienen *et al.,* 2015, Poorter *et al.,* 2016).

During the early twentieth century, standing old-growth tropical forests removed 1-1.2 Pg carbon y-1 and regrowing (or secondary) forests another 1.2-1.7 Pg y-1, which was about 24% of the worldwide yearly anthropogenic carbon emissions (Canadell and Schulze 2014, Goodman and Herold 2014). Third, tropical forests reduce worldwide temperatures because of high evapotranspiration rates. High evapotranspiration directly affects temperatures through evaporative cooling, and an indirect impact through increasing cloud and rainfall formation and sunlight reflection which, in turn, decrease global temperatures (Alkama and Cescatti 2016).

A part from their climate mitigation capacity, tropical forests are crucially important for various other functions that are relevant at local and global scales, such as timber and non-timber forest products and pollination (Alkama and Cescatti, 2016). Globally, the livelihood of more than a billion people depends directly on forests (FAO, 2016), with most of them living in the tropics. Forest functioning ultimately depends on ecosystem processes, which are fluxes of carbon, water and nutrients at the ecosystem level. To guarantee forest functioning, we thus need to understand what mechanisms determine ecosystem processes.

Tropical forests are significant in addressing global climate change (Lewis *et al.*, 2009). At the global level, forest ecosystems could play a significant role in atmospheric carbon sequestration. On the other hand, vulnerable poor communities rely upon forest goods and services to adapt to impacts of climate change at the national and local levels, which the current study addresses. The idea of ecosystem services gained more attention after the Millennium Assessment defined it (TEEB Foundations, 2010; TEEB Synthesis, 2010; Ninan, 2014).

Ecosystem services got from the natural capital, which adds to accomplish human prosperity by interacting with built capital (financial and manufactured capitals), social capital, human capital and natural capital (Ninan, 2014). However, human wellbeing, livelihoods and ecosystems around the globe are being threatened by climate change and climate related disasters (Lo, 2016).

The MA (2005) showed illustrated ecosystem services as the benefits people acquire from ecosystems. This idea is easily comprehended and conceptually simple but covers most of the services benefitting human beings; hence the MA approach is widely utilized in ecosystem services research (Baral *et al.*, 2014; Burkhard *et al*., 2012; Pert *et al.*, 2015).

Plate 2.3: The Kakamega Tropical Rainforest is a magnificent habitat for biodiversity
Source: Researcher (2021)

The supply of ecosystem services in a forested landscape varies due to differences in vegetation type and cover (Burkhard *et al.*, 2012; de Groot *et al*., 2010), and environmental factors and forest management systems (Palomo *et al*., 2013). The interaction among ecosystem services may also be different depending on the ecosystem services under consideration (Harrison *et al.*, 2014). Therefore, a solid understanding of the distribution of ecosystem services across the forested landscape, together with quantifying interactions between ecosystem services and environmental drivers is enormously important.

However, very little is known about ecosystem services science in tropical forests (Alamgir *et al.,* 2014; Seppelt *et al*., 2011; Seppelt *et al.,* 2012). The heterogeneous tropical forested landscape of the Kakamega Tropical Rainforest may provide an opportunity to understand the process and interactions of multiple ecosystem services

supply, thereby contributing to this knowledge gap.

.

Plate 2.4: The damage of forest canopies in the Kakamega Tropical Rainforest
Source: Researcher (2021)

Kakamega Tropical Rainforest includes a large variety of ecosystems (Pittock *et al*., 2012) and its natural ecosystem is one of the most vulnerable segment to climate change (Smith and Ash, 2011). Under the most recent climate change projections (IPCC, 2014),the ecosystem services supply from forested landscapes is likely to be under more pressure in this century. However, the trend is yet to be explored for most terrestrial forest ecosystems, particularly for remaining areas of tropical forest of global significance.

Each forest type forms a habitat for a specific community of animals that are adapted to live in it as shown in figure 2.3. The term forest implies ‘natural vegetation’ of the region, 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 daily life, play important role in maintaining ecological balance, and contributes to economy (State of Environment Report – India, 2009).

Tropical rainforest assumes a significant role in the worldwide carbon cycle (Huntingford *et al.*, 2013), accounting for a large portion of global Net Primary Productivity (NPP) and bringing down atmospheric CO_2 levels. The Central American rainforests are mainly found on the Caribbean watersheds of Panama, Costa Rica, Honduras, Belize, and southern Mexico. The area is a global biodiversity hotspot that is highly threatened by change of land use. In Central America, impacts like those that happened during El Nino years are likely to increase under future climatic scenarios (Karmalkar *et al.*, 2011). Similar to the Amazon, Central America is subject to potentially large losses of forest biomass under increased drying and warming scenarios in the twenty-first century (Lyra et al., 2016; Imbach *et al.*, 2012).

The MA (2003, 2005) was the first global dynamic and integrated document that reported on Ecosystem Service research globally. It established Ecosystem Service as a policy tool for sustainable natural resource management (Seppelt *et al.*, 2011) as well as providing scientific evidence for policy makers about the consequences of changes of Ecosystem Service to human wellbeing (Pert et al., 2010). Scientists and policy makers have continued to conduct further ES research as of late (Fisher *et al*., 2009). For instance, Seppelt *et al.*’s (2011) global review on ES studies evaluated the current trend, spatial distribution, weakness and future direction of ES research, whilst

Egoh *et al*., (2007) completed a global review on ES studies, focusing on conservation assessment.

Many studies refer to the key role of ecosystems in climate change adaptation and disaster risk reduction, since ecosystems provide many ecosystem services, including: natural protection against hazards, climate and water regulation, carbon sequestration, and pest regulation. In addition to this, management of ecosystems increases the resilience of the ecosystems and communities to climate change and disasters (Munang *et al.,* 2013).

2.4 Impacts of Climate Change on Kakamega Tropical Rainforest Ecosystem

Climate change has increased the risk of catastrophic natural disasters all over the globe(Kabubo-Mariara and Kabara, 2015). Despite the fact that the impacts of the changes are worldwide, developing countries are more in danger, basically on account of their high reliance on natural resources, poverty, low capacity to adapt (Bryan *et al.,* 2013; Kabubo-Mariara and Kabara, 2015), lack of technological capability (Mwendwa and Giliba, 2012) and the presence of environmental stress (Norrington-Davies and Thornton, 2011). Also, almost no data about the change and applicable mitigation and adaptation measures fuel the circumstance in developing countries. Despite the fact that agriculture remains the backbone of Kenya's economy directly and indirectly supporting more than 75 percent of the Kenyan populace (FEWS NET, 2013), the sector's reliance on natural resources makes it very vulnerable to the impacts of climate change and variability.

Perhaps, the most severe is the impacts of weather extremes on NTFPs, which are becoming scarcer by the day. Changing climate patterns cause biodiversity loss, as forest plant species become extinct, leading to further ecological destabilization and an alteration of community livelihoods in the affected areas (Dube *et al.,* 2016). However, Seppala *et al.* (2009) notes that climate change effects on NTFPs are still not clear, as there is still uncertainty regarding the ecological effects. Needless to say, NTFPs thrive on the delicate balance of natural factors.

The direct impact of climate change on human health is rather small at this point in time; it is the indirect effects that matter more – for example the effects on ecosystems on which people rely. Various levels of government are starting to develop adaptation plans and policies by integrating them into broader development plans. This suggests that governments are trying to integrate climate change considerations into development planning (IPCC, 2014).

The impacts of climate change may have direct impacts on vegetation, like, changes in productivity, functional trait composition and species extinction or range redistribution. These changes might be associated with increased drought stress (Malhi *et al.*, 2009), drying or dieback. Climate change can also have indirect impacts on vegetation, for example, increased fire frequency. Worldwide and regional climate simulations for the next few decades project changes in precipitation and warming that may seriously impact major biomes all over the world (IPCC, 2013).

Climate change impacts are expected to disproportionally worsen poverty conditions, especially in rural areas that have natural resources-based economies likely to be negatively affected by flooding and drought that further exacerbate their poverty (Olson *et al*. 2014). According to the International Panel on Climate Change (IPCC), climate change adversely influences poor livelihoods and assets by mainly negatively affecting agricultural production and food price, and through climate disasters (Olsson, *et al*. 2014, Hertel, *et al.* 2010). Rural households' livelihoods, such as planting crops, extracting forest products and raising livestock, largely depend on natural resources, making them generally more exposed and sensitive to climate variations and climate disasters.

Tourism is another key sector in Kenya's economy contributing 10 percent of Kenya's GDP (GoK, 2013). However, the sector is highly susceptible to climate change and variability, since there will be shift of ecosystem boundaries in natural habitats and increased extinction rates of some species (Reid, 2004). There may be a reduction of landscape aesthetics and higher incidence of vector-borne disease (Kithiia, 2011; GoK, 2013). There is growing evidence that the world is already locked into warming of close to 1.5°C above pre-industrial levels, getting effective methods for adaptation that are also cost-effective has become both urgent and essential (World Bank, 2014). As weather extremes become more common, and increased climate variability increases risks to energy security, water, and food, harnessing the power of nature through EbA is important to help address these challenges.

Shaw et al., (2011) have evaluated the climate change impact on California's Ecosystem Service under IPCC (2007) high and low greenhouse gas emission scenarios using Dynamic Global Vegetation Model (DGVM). They have discovered that the provision and value of Ecosystem Service will decrease under most of the future greenhouse gas trajectory. Ding and Nunes (2014) have as of late modelled the impact of climate change on Ecosystem Service across European forests. They have discovered that climate change impacts on Ecosystem Services are regionally specific. They have additionally discovered a solid relationship between temperature and the value of Ecosystem Services; however the direction of the relationship may be either positive or negative depending on the type of Ecosystem Service under consideration.

Other than the climate change alleviation capability of tropical forests, tropical forests are also significantly influenced by worldwide climate. Increasing atmospheric Carbon dioxide concentrations, increasing temperature, and changing rainfall patterns will pose a challenge to the functioning of forests (Brienen *et al.,* 2015). Whether ecosystem functioning will be maintained depends on whether species can adapt or acclimate to new a biotic conditions, and/or whether species composition can change so that better adapted species become more dominant. The questions are, therefore, how tropical forests respond to changes in abiotic condition, and how biotic conditions (for example the type and assorted diversity of species) contribute to this response capacity.

Evidence is increasing that old-growth tropical forests are not in a stable state but are accumulating biomass (Brienen *et al.*2015) and are changing in species composition (for example Enquist and Enquist 2011, Feeley *et al*., 2011). In accordance with the insurance theory (Yachi and Loreau 1999), several studies in grasslands and temperate forests find that biotic conditions, particularly species and trait diversity, are important for increasing the long-term stability of ecosystem processes (Hector *et al*. 2010, Morin *et al.* 2014).

This phenomenon, however, has yet not been demonstrated for tropical forests because, due to their high diversity, high structural complexity, and the long turnover time of most tropical tree species, it is difficult to assess this relationship empirically. Global dynamic vegetation models that include realistic levels of diversity (Sakschewski *et al.,* 2015) may provide an opportunity to evaluate effects of diversity on the long-term stability of tropical forests. This knowledge is crucial because tropical forests are important for global climate now, and should be so too in the future.

Biodiversity misfortune and Climate change are among the primary worldwide challenges within recent times; the two, suggest the likely reduction in capacity of ecosystems and debasement of ecosystem functions and services (Steffen *et al.,* 2015). While climate change mitigation involves mediations to lessen the sources or to upgrade the sinks of ozone depleting substances (Victor *et al.*, 2014), climate change adaptation is commonly characterized as 'modifications in human or natural systems in light of expected or real climate stimuli or their impacts, which moderate damage or endeavor openings'.

2.5 Ecosystem-based Adaptation to Climate Change in Kakamega Tropical Rainforest

There are varying definitions of the idea of Ecosystem-based Adaptation – while at the same time a common, generally accepted definition of the idea is missing (UNFCCC SBSTA, 2013). The most cited definition in the scientific literature is noted by the CBD in 2009. It explains that:

> "Ecosystem-based Adaptation is the use of biodiversity and ecosystem services as part of an overall adaptation strategy to help people to adapt to the adverse effects of climate change. Ecosystem-based Adaptation uses the range of opportunities for the sustainable management, conservation, and restoration of ecosystems to provide services that enable people to adapt to the impacts of climate change. It aims to maintain and increase the resilience and reduce the vulnerability of ecosystems and people in the face of the adverse effects of climate change."(CBD, 2009, p. 41).

Ecosystem-based adaptation is most appropriately integrated into broader adaptation and development strategies (Renaud *et al*., 2016). Based on their concepts the main difference between them is that each approach addresses a specific issue, Disaster Risk Reduction (DRR) and Climate Change Adaptation (CCA) (Renaud *et al.*, 2016).

One year after framing it in this manner, the explanation was further elaborated by the Convention of Biological Diversity at the 10th CBD COP that was held in Nagoya, Japan. In decision X/33 it is documented that the Conference of the Parties recognizes, that the ecosystem-based approach:

> *"may include conservation, restoration of ecosystems, and sustainable management, as part of an overall adaptation strategy that takes into account the multiple cultural, economic and social co-benefits for local communities." (CBD, 2010, p. 3).*

There exist other definitions that are different slightly from the one of the CBD, for example, Jones *et al* (2012) avers that Ecosystem-based Adaptation measures harness the capacity of nature to buffer human communities against the adverse impacts of climate change through the sustainable delivery of ecosystem services. As such, Ecosystem-based Adaptations are generally deployed in the form of targeted management, conservation and restoration activities, and are often focused on specific ecosystem services. According to Ahmmad *et al.*, (2013), Ecosystem-based Adaptation refers to use of natural resources through conservation and enhancing resilience of ecosystem to buffer the worst impacts of climate changes on species and well-being of community.

United Nations Framework Convention on Climate Change technical workshop of the Subsidiary Body for Scientific and Technological Advice in Bonn in 2013 on Ecosystem-based Adaptation, an interesting outcome was documented that critically reflects on the strong anthropocentric notion of the concept. Seventy-three representatives had attended the workshop from Parties with relevant international, non-governmental organizations and intergovernmental that are active in the fields of climate change impact and vulnerability assessment, and adaptation planning and practices including those related to ecosystem-based approaches for adaptation (UNFCCC SBSTA, 2013).

Those who participated in the workshop noted that when defining ecosystem-based approaches for adaptation, there must be a shift from a purely anthropogenic perspective to one that embraces both ecosystems and people. In addition, the participants pointed out that a conceptual separation between adaptation of ecosystems and ecosystem-based approaches for adaptation is required, while recognizing the broader role that ecosystems could play in actions to ameliorate the impacts of climate change (UNFCCC SBSTA, 2013). This articulation of the need to reconsider the conceptual design of the Ecosystem-based Adaptation could be the beginning of a conceptual discussion over the concept. It shows clearly that the concept is currently in its nascent stages.

According to Doswald *et al*., (2014) some organizations still conceptualize Ecosystem-based Adaptation as the adaptation of ecosystems to climate change, rather than the use of ecosystems for human adaptation to climate change. Here, the use of the word 'still' is particularly interesting as it suggests to the reader that 'only some organizations do not entirely fathom what the concept is all about and may apply it in a wrong way'. The paper argues that there are a number of studies trying to catalyze the understanding of the concept by formulating guiding principles and guidelines, but still there is a confusion about the meaning. The necessity remains to work further on the conceptual outline of the concept of Ecosystem-based Adaptation in order to bring all sides on the same page (Doswald *et al.,* 2014). Framing it from an ecocentric perspective would imply that the concept means an adaptation of ecosystems to the change of climate.

Renaud et al.,(2016) defines Ecosystem-based Disaster Risk Reduction (Eco-DRR) as the sustainable management, conservation, and restoration of ecosystems to reduce disaster risk, with the aim of achieving sustainable and resilient development. After finding many converging points between these two approaches, another concept has arisen to emphasize the benefits that ecosystem-based approaches provide to achieve both DRR and CCA. Finally, Eco-DRR/CCA complements other disaster risk reduction and climate change adaptation measures. In addition, ecosystems provide other co-benefits to societies such as water and soil protection, contribution to sustainable livelihoods, carbon storage and sequestration (Lo, 2016).

Considering change of climate in development activities could add a long term sustainability component to official development assistance. However, national governments and development agencies challenged to practice a ‘no-regrets’ climate change interventions that should reduce rather than increase vulnerability to climate change (Heltberg *et al.*, 2009). Vulnerability to climate change can be minimized by adaptation to the impacts of climate change and mitigation of greenhouse gas emissions. It can also be reduced by development aimed at improving the living conditions and access to resources for those experiencing the impacts, as this will enhance capacity to adaptation (Ayers and Huq 2009).

Adjusting to a change in climate requires a blend of approaches, from man-made infrastructure to all-encompassing methodologies (UNEP, 2012). The United Nations Environmental Program (UNEP) is investigating the practices and standards of another idea that incorporates ecosystem management practices into climate change adjustment plans (UNEP, 2012). Ecosystem based Adaptation (EbA) is a novel way to deal with planning and adjustment that recognizes ecosystem services, upgrading biodiversity, human health and wellbeing as prosperity areas (Colls, *et al.* 2009).

Some researchers have evaluated the impacts of different climate change scenarios on alternative spatial policy options (Bryan *et al.*, 2011), mapped ecological values of habitat of threatened species due to climate change (Bryan *et al.*, 2011), examined the variation of nutrient retention in tidal mangroves with rainfall variation (Adame *et al*., 2010), considered species' responses to climate change as one of the indicators for investment decisions (Crossman *et al.*, 2011), conceptualized the adaptive capacity through learning from historical examples (Bussey *et al.*, 2012), and assessed usefulness of agro forestry systems for carbon sequestration and other Ecosystem Services in the face of climate adaptation and mitigation (George *et al.,* 2012).

Bennett *et al.*, (2009) in a survey, presented three hypotheses to accomplish improved management of relationships among multiple ecosystem services. First and foremost, an integrated socio-ecological strategy may give a superior evaluation or identification of relationships. Secondly, understanding the mechanisms that influence responses of multiple services to a specific driver may help identify points of management intervention that can yield maximum benefits. Thirdly, managing the relationship among ecosystem services can enhance ecosystem resilience and continuous provision of services, and prevent a sudden shift in the provision of ecosystem services.

Climate change adaptation integrates a variety of measures. They can be broadly classified into 'hard' and 'soft' approaches. 'Hard' approaches focus on engineering and physical solutions while 'soft' approaches for the most part center around institutional functions, capacity building, information and policy (Jones *et al.*, 2012). In the extensive field of climate change adaptation practices, Ecosystem-based ways to deal with climate change adaptation are measures which use ecosystem services to achieve or bolster adjustment to climate change. There is developing enthusiasm for the capability of Ecosystem-based measures, either combined with or subbing other innovative engineered and technological solutions, to guarantee security of benefits and the wellbeing of the population, including ecosystems and their services (Noble *et al.,* 2014).

Conceptually, Ecosystem-based Adaptation is grounded in the ecosystem services idea. Ecosystems are comprehended as dynamic complex of plant, animal and micro-organism communities and their non-living environment, which interact as a functional unit. Ecosystem services are the ecological characteristics, processes or functions that directly or indirectly contribute to human wellbeing that is to the advantages that individuals get from functioning ecosystems (Folke *et al.,* 2010). In this context, Ecosystem-based Adaptation also builds on ideas like disaster risk reduction where ecosystems are deployed in risk reducing measures, and resilience which emphasizes that the services of well-functioning ecosystems strengthen the capacity of socio-ecological systems to remain within a stability domain, continually changing and adapting yet remaining within critical thresholds (Folke *et al.,* 2010).

Ecosystem based Adaptation, purposively uses 'green infrastructure' and ecosystem services to increase human societies' resilience in the face of climate change. Hence, EbA is an anthropocentric approach concerned with the way ecosystems can help people adapt to both current climate variability and future climate change (Lemos et al., 2016). Its main objective is always to reduce the vulnerability of people towards the effects of climate change. EbA is complementary or even substitutes other adaptation measures, such as hard or 'grey' infrastructure measures.

Additionally, the ecosystem-based, natural solutions tend to generate valuable co-benefits, such as food production, carbon sequestration, orbiodiversity conservation, and are often more cost efficient. For instance, it has been found in Vietnam that planting and maintaining mangrove forests to act as breakwaters and protect the coast is significantly cheaper (costing 1.1 million US dollars for 12,000 hectares) than mechanical repair of wave-induced dyke erosion (costing 7.3 million US dollars annually) (The Economics of Ecosystems and Biodiversity, 2009).

Since 2010, a number of policy initiatives have been undertaken in Europe to invigorate implementation of Ecosystem-based Adaptation, for example through the European Union technique on adaptation to climate change which has focused on considering private organizations, civil society and practitioners in conservation (EC, 2013). Besides, the European Union came up with a research and innovation plan strategy for the later idea of 'nature-based solutions' (NBS) including business partners, societal and policy. The Nature Based Solutions strategy builds on the ideas of EbA and ecosystem services. Nature based solutions alludes to activities which are upheld by, aroused by or duplicated from nature, that is, got from the perception of natural materials or processes. Since NBS defenders had proclaimed climate change adaptation as one of the primary areas of use, implementation of NBS both at the policy level and task level is additionally significant for the uptake of EbA in policy and practice (EC, 2015).

EbA utilizes ecosystem services and biodiversity to help individuals to adjust to the unfavorable impacts of climate change (Secretary of Convention on Biological Diversity, 2009) and regularly overlaps with other socio-economic goals, for example, sustainable development and poverty reduction (Munang *et al.,* 2014). In China, poverty largely overlaps with ecologically vulnerable regions that are sensitive to climate change (Oxfam 2009). China's southwest mountainous region, albeit high in biodiversity, is one of the most ecologically vulnerable regions in the country.

Adaptation planning typically incorporates "hard" and "soft" approaches. Soft approaches are usually employed first and refer to policy and behavioural changes (Clark *et al.,* Jones, Hole, and Zavalta, 2012). Hard infrastructure refers to manmade infrastructure, such as "dams, irrigation systems, reservoirs, dykes, seawalls, levees, river channelization, and rip-rapping (Clark *et al*, 2012). Jones *et al*. (2012) considers EbA approaches the third category of adaptation approaches, as it requires a combination of both hard and soft approaches. As Jones *et al*. (2012) explains, "EbA is generally deployed in the form of targeted management, conservation and restoration activities, and are often focused on specific ecosystem services with the potential to reduce climate change exposures".

Ecosystem based Adaptation is a novel strategy to planning and adaptation that prioritizes ecosystem services, enhancing biodiversity, as well as human health and wellbeing (Colls, Ash, and Ikkala, 2009). The idea evolved from the association between Ecosystem Based Management and climate change adaptation actions. Ecosystem Based Management (EBM) is "an adaptive way to managing human activities that seeks to ensure the coexistence of healthy, fully functioning ecosystems and human communities. The intention is to maintain those spatial and temporal attributes of ecosystems such that component species and ecological processes can be sustained, and human wellbeing supported and improved" (Price *et al*., 2008).

As depicted above, climate change adaptations are activities taken to mitigate the negative impacts or take advantage of new opportunities of climate change. Ecosystem based Adaptation is a combination of both of these EBM and climate change adaptation and remains relatively new in practice but is being deemed "a cost effective operational tool that can complement, if not substitute, traditional hard infrastructure practices" (UNEP, 2012).

Traditionally, EBM is applied in resource management issues from forestry to fisheries practices. EBM is a planning approach that incorporates multiple issues into one management strategy, from individual species to whole ecosystem functions (Travers, Elrick, Kay, & Vestergaard, 2012). EBM is an innovative management regime because it acknowledges the rich complexity of ecosystems and attempts to identify, protect, and where necessary, restore important interactions. More specifically, EBM considers human activity in the specific management context and allows multiple activities to be managed for a common outcome (UNEP, 2012).

EBM focuses on a holistic approach to support an optimal management response (Travers, Elrick, Kay and Vestergaard, 2012). When climate change adaptation and EBM are practiced in tandem, the result should be a systems-based strategy “that considers all significant drivers and reactions to change, including, climate-driven change, disaster risk response, climate variability, and broader long-term socio-economic change” (Travers, Elrick, Kay and Vestergaard, 2012). A fundamental feature of Ecosystem based Adaptation is the consideration of existing ecosystem services and how they are used for human wellbeing (Huq *et al.*, 2013; Munang *et al,* 2013).

National Adaptation Plan (NAP) system in Colombia was developed by the government in 2011 to address climate change, defining guidelines for various segment and regions to lessen vulnerability and incorporate climate change and climate variability in their planning approaches. In total 11 territorial climate change adaptations have been formulated (Huq *et al.,* 2013). The EbA and Eco-DRR measures currently implemented include: rehabilitation of wetlands to reduce flooding risk and drought related to climate change and variability, and adaptation measures to mitigate climate change on the water yield and hydrological regulation capacity of wetlands and high mountain ecosystem. Other key ecosystems they considered are Moors (Paramo, Andean woodlands), high Andean forest, cloud forest and tropical forest (Lo, 2016).

Restoration of highly degraded dry forests in Colombia was implemented by the Alexander von Humboldt Research Institute of Biological Resources, along with other institutions in the Ituango Municipality, Department of Antioquia (McBreen, 2016). The restoration activities will be accomplished through three pilot projects to compensate environmental harm brought about by the construction of a reservoir, and to add to the conservation of the delicate dry forest ecosystem of the region. The project will work as a reference for compensation (McBreen, 2016).

Some examples of ecosystem-based approaches for adaptation include: the maintenance and restoration of “natural” or “green” infrastructure for example mangroves, coral reefs as well as watershed vegetation as buffer zones that reduce climate risks (e.g. the use of coastal ecosystems to reduce risk of flooding and erosion from storm surges and rise in sea-level); the maintenance of agricultural landscapes to support productivity and avoid soil erosion under changing conditions e.g. introduction of agro forestry and soil conservation practices in the upstream areas of water catchments to avoid soil erosion, siltation, and large changes in hydrological regime (CBD, 2009).

While adopting this approach is cost-effective and locally appropriate, it also contributes to reduction of biodiversity loss and maintaining or improving ecosystem services that support livelihoods and economic activities (for example fish spawning as well as nurseries in protected mangroves and tourism in sustainable managed coastal areas) (CAN, 2009). Thus, this approach can serve multiple roles and gives multiple benefits (for example conservation of tropical forests supports a range of products critical for poor communities, protects against erosion, contributes to mitigation through both maintaining and increasing carbon storage, increases water storage capacity, provides wood fuel, maintains biodiversity and offers renewable raw materials and shelter) (CAN, 2009). Given the above, this approach is not only of high value for adaptation, but is aligned with local needs, capabilities and development objectives.

Convention on Biological Diversity explained the idea of Ecosystem based Adaptation in the year 2009 and on its twelfth COP in 2014, advances a stronger purpose for biodiversity conservation and implementation of EbA to climate change mitigation and adaptation, so as to enhance disaster risk reduction in local and national strategies as well as in National Adaptation Plans (NAPs) (Estrella *et al.,* 2016). Ecosystem-based Adaptation (EbA) utilizes biodiversity and ecosystem services as part of an overall adaptation strategy to assist people and communities adapt to the negative impacts of climate change at local, national, regional and global levels (UNEP, 2014).

Approaches include sustainable management, conservation and restoration of ecosystems for the purpose of providing services to help people adapt to climate change impacts. Specifically, for terrestrial forest communities, EbA may include interventions of conserving or restoring forest on the land slope to reduce landslides or losses of water (Pramova *et al.* 2012); or developing diversified agroforestry to deal with climate variability (Thorlakson, T. and Henry, N. 2012); and conservation of agro biodiversity to give particular gene pools for crops or livestock to adapt to climate change.

EbA as a natural answer to climate change has been acknowledged to also have many co-benefits beyond the adaptation (UNDP 2015). Studies have shown that EbA can be more cost-effective and accessible to rural communities than adaptation interventions that use hard infrastructures or engineering methods (Jones *et al.* 2012, Vignola *et al*. 2015). In rural areas, Ecosystem based Adaptation usually overlaps with other socio-economic goals such as sustainable development and poverty alleviation, especially for smallholder farmers (Munang *et al*., 2014). In terms of evaluating the outcome of EbA, 63% of peer-review papers and 31% of grey literature show quantifiable evidence of success (Doswald, 2014).

Additional ways in which ecosystems function that can be connected to climate change disaster risk reduction is the protection of forests against landslides or avalanches in mountainous areas for example measures are being implemented in the Alp area by the Swiss government to protect villages (Uy, 2012). Catchment areas forests can decrease the risks of floods by increasing infiltration of rain and delaying peak floodwater flows. Floodplains as well as Wetlands can control floods in coastal areas or inland river basins. In dry lands, vegetation cover can function as physical firebreaks, ameliorate droughts and control desertification (Uy, 2012).

Munang *et al.*,(2013)points out that Ecosystem based Adaptation gives a lasting and sustainable set of solutions in a cost effective manner to deal with climate change and sustainable development constraints. It is pointed out that in situations where measures of hard infrastructure utilized to be implemented, for example for coastal protection – ecosystem-based solutions could offer a cost effective alternative.

The major benefit of Ecosystem based Adaptation over other adaptation strategies is the provision of multiple co-benefits to society (Munang *et al.*, 2013). Emerging literature promotes Ecosystem based Adaptation as applicable to both developed and developing countries (Munang *et al*., 2013). The co-benefits of Ecosystem based Adaptation help attain multiple policy and environmental goals to address climate change. For instance, protecting or restoring natural infrastructure such as barrier beaches, mangroves, coral reefs, and forests buffers human communities from natural hazards, erosion, and flooding (Munang *et al.*, 2013).

A part from economic and environmental advantages of Ecosystem based Adaptation, there is tremendous opportunity to improve the social experience of people residing in close proximity or visiting green spaces in urban regions. The significance of green spaces and intact ecosystem for residents are many and extensively cited in the literature (Elmqvist, 2015; Zupancic, 2015; Demuzere *et al.,* 2014; Zhou and Parves, 2012).

Ecosystems that are health can play an important purpose in disaster risk reduction. They can serve as natural buffers or protective barriers to floods and landslides. They can also effectively serve as water filtration and absorption systems (Renauld *et al.,* 2013). Ecosystems that function fully can additionally build resilience against disasters by sustaining human livelihoods and giving essential goods to local populations, such as food and shelter. As a result, the Ecosystem based Adaptation and Disaster Risk Reduction practitioner communities are now joining together to explore how to better use nature-based measures to reduce the damage caused by disasters, involving those increased by climate change (Zhou and Parves, 2012).

In order to understand the interactions between climate change, disasters, and ecosystems, and to effectively plan solutions at the local level, participatory tools are appropriate alternatives as they allow combining indigenous knowledge with scientific information (UNDP, 2016). It also allows a better understanding of the perception of communities that are always the most vulnerable to climate change and disasters as they have limited access to those resources that would facilitate their resilience (CARE International, 2009). The 17 Sustainable Development Goals (SDGs) were adopted by the UN General Assembly in September 2015 and came into effect in January of 2016. It is also a 15-year agenda that aims to protect the planet and ensure prosperity for all. Some of these goals refer to the role of ecosystems services for climate change adaptation and disaster risk reduction (UNDP, 2016).

One thing to be noted with regard to shortcomings relates to lack of a universally accepted definition of EbA. Other sources conclude that this may be a reason why decision makers hesitate in undertaking Ecosystem-based Adaptation with consideration of other adaptation options (Doswald *et al.*, 2014). It is also vivid that Ecosystem-based Adaptation can come in many forms. Combined with the unclear definition, the field becomes rather blurry making it increasingly difficult to compare amongst different Ecosystem-based Adaptation measures.

The investigation of entrepreneurs in EbA can draw on conversations in the writings on climate change adaptation about the roles of private and public actors for adaptation (Klein, *et al.*,2017) and the provision of adaptation goods by private actors (Tompkins and Eakin, 2012). Further, the writing on social-ecological systems and resilience gives insights in the variegated approaches of entrepreneurs, involving the mobilization of social networks, trust building, generation of knowledge and the creation of public awareness for environmental problems (Evans *et al.*, 2015).

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

2.6 Challenges and Constraints Facing Implementation of EbA Initiatives in Kakamega Tropical Rainforest

Present knowledge of the mechanisms and relationships between many ecosystem processes and most services remain weak (Carpenter *et al.*,2009). This restricts our comprehension on how and when to decrease trade-offs and promote synergies among ecosystem services (Bennett *et al.*, 2009). This impediment has also driven humanity to concentrate on the most desired ecosystem services that have resulted to an increase in a few goods and services like fiber, food, and timber and a decline in other services like pollination, genetic resources, combating desertification, and flood control.

Despite the fact that there is colossal proof about the capability of Ecosystem based Adaptation, limitations remain for its ability to satisfy all adaptation requirements. The impediments exist because of the continued uncertainties around future climate conditions (Jones *et al.*,2012). Climate change predictions are presented in a variety of situations. Addressing future needs through adaptation actions is like hitting a moving target for adaptation planners. At the same time, the complex interactions of ecosystems needed for optimal ecosystem service delivery is hard to quantify (GOK, 2012). When the impact of climate change on ecosystems is considered in tandem with resulting impact to ecosystem services, significant uncertainty around the delivery of ecosystem services under various climate change conditions remains (Jones *et al*., 2012).

In other words, adaptation planners need to picture out the adaptive capacities of ecosystems under future climate change situations. Additionally, global practices of consumption, that is forestry, fishing, mining, transportation and development are all exerting pressure on ecosystems that may give adaptation services; therefore, knowing which services are threatened by particular actions is also vital for adaptation planners (Jones *et al.*, 2012).

Higher population growth rate is also another social issue affecting adaptation strategies. A constricted resource base and an annual population growth rate of 2.1 percent (GOK, 2012) leads to increased degradation of the environment as well as increased deforestation due to settlement and fuel-wood.

Areas where deforestation has taken place typically experience extreme soil erosion and often degrade into wasteland. Moreover, these disregard or ignorance of intrinsic value, lack of ascribed value, careless forest management and incomplete environmental policy are some of the factors that necessitate deforestation to occur extensively (Butler, 2009). There exists numerous underlying drivers of deforestation, such as corruption of government institutions, the inequitable distribution of wealth and power, increase in population, overpopulation (Butler, 2009) and growth of urban areas. Globalization is frequently seen as another main driver of deforestation, however there are cases in which the impacts of globalization (new flows of labor, capital, commodities, and ideas) have advanced localized forest recovery.

In numerous nations, deforestation is a continuous issue that is causing extinction of species, changes to climatic conditions, aridity and desertification, and displacement of homegrown population. In the year 2000 the United Nations Food and Agriculture Organization (FAO) found that the role of population changes in a local setting may differ from decisive to negligible and that deforestation can result from a combination of population stress and stagnating economic, social and technological conditions (The New York Times, 2009). Moreover, it facilitates the rate of drought occurrences, limits poverty reduction goals, and leads to low living standards of people and can be a cause for political instability of a country. Among nations 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).

To the poor who depend on forest ecosystems, forests link with poverty in a complex way. On one hand, forests provide them with food, timber products and non-timber products, ecosystem services, and employment opportunities that could help them reduce their poverty. On the other hand, living in rural forest areas means heavily depending on natural-resources that are increasingly unstable due to environmental changes like land degradation and climate change (Maraseni, 2012) which in turn may lead to further poverty. Moreover, poverty in forests may also be caused by economic reasons like the fluctuation of markets, physical reasons like remoteness, and other social-political reasons such as the marginalization of certain groups (i.e. ethnicity, gender), inequality, lack of land rights, low capacity of local institutions and management systems, and unequal forest policies (Maraseni, 2012).

There exists very few studies about Ecosystem based Adaptation and climate change for Kakamega Tropical Rainforest. Ecosystem based Adaptation is a relatively new idea in practice and there is absence of data about Ecosystem based Adaptation technologies compared to man-made infrastructure adaptation solutions (Travers, Kay, Carmen Elrick and Vestergaard, 2012). Another major aspect which is not sufficiently covered by the literature and the studies surrounding the idea is time and timescale. Adaptation is a long-term issue and the success of an intervention may show itself a long time after a project has been implemented. It is therefore essential to have evidence regarding timescales. Doswald *et al.*, (2014) suggests a better consolidation of knowledge, research and monitoring on timescales.

Quite a number of advantages are attributed to EbA. However, various investigations on EbA remain anecdotal case studies of its success. There have been few systematic studies on its effectiveness and only a limited number of reviews of the existing case studies in the field. This suggests that the evidence base is thus lacking information (Doswald *et al.*, 2014). Considering this, a shift of focus towards the challenges and limitations of the concept seems necessary.

However, there are growing evidence that anti-poverty interventions can and do work as in, for example, the Millennium Development Goals program, through which absolute poverty dropped by nearly half (United Nations 2015). Hence understanding the factors that drive their success is paramount (Lemos *et al.*, 2016).

2.7 Theoretical Framework

This study utilized two theories:

2.7.1 Anthropogenic Global Warming Theory(Raven,et., al., 1999; Sarmiento, et. al., 1998)

This theory of climate change contends that human emissions of greenhouse gases, chiefly nitrous oxide, methane, and carbon dioxide, are causing a catastrophic rise in global temperatures. The mechanism whereby this happens is called the enhanced greenhouse effect. This theory is referred to as anthropogenic global warming (AGW). Energy from the sun travels through the atmosphere and reaches Earth. The Earth's atmosphere is often transparent to the incoming sunlight, allowing it to reach the planet's surface where some of it is absorbed and some is reflected back as heat out into the atmosphere. Certain gases in the atmosphere, called "greenhouse gases," absorb the outgoing reflected (terrestrial radiation) or internal thermal radiation, re-sulting in Earth's atmosphere becoming warmer than it otherwise might be (Raven, *et., al.,* 1999).

Water vapor is the main greenhouse gas, responsible for about 36 to 90 percent of the greenhouse effect, followed by Carbon dioxide (<1 to 26 percent), methane (4 to 9 percent), and ozone (3 to 7 percent). (These estimates are the subject of much dispute, hence their wide ranges). During the past century, human activities such as burning wood and fossil fuels and cutting down or burning forests are thought to have intensified the concentration of Carbon dioxide in the atmosphere by approximately 50 percent. Continued burning of fossil fuels and deforestation could double the amount of carbon dioxide in the atmosphere during the next 100 years, assuming natural "sinks" don't grow in pace with emissions (Sarmiento, *et. al*., 1998).

The Earth's climate also responds to numerous other types of external influences, such as variation in solar radiation and in the planet's orbit, but these "forcings," according to the proponents of AGW, cannot explain the increase in Earth's temperature over the past thirty years. The forcing caused directly by man-made greenhouse gases is also small, but the AGW theory posits that positive feedbacks increase the effects of these gases between two- and four-fold. A small increase in temperature leads to more evaporation, which places more water vapor in the atmosphere, which causes more warming. Global warming may also result in less ice and snow cover, which would lead to more exposed ground and open water, which on average are less reflective than snow and ice and thus absorb more solar radiation, which would cause more warming. Warming also might trigger the release of methane from frozen peat bogs and Carbon dioxide from the oceans(Raven, *et., al.,* 1999).

Supporters of the AGW theory contend the ~0.7°C warming of the past century-and-a-half and ~0.5°C of the past 30 years is mostly or entirely attributable to man-made greenhouse gases. They dispute or disregard claims that some or perhaps that entire rise could be Earth's continuing recovery from the Little Ice Age (1400-1800). They utilize computer models based on physical principles, theories, and assumptions to predict that a doubling of Carbon dioxide in the atmosphere would cause Earth's temperature to rise an additional 3.0°C (5.4°F) by 2100(Raven, *et., al.,* 1999).

When these climate models are run "backwards" they tend to predict more warming than has actually occurred, but this, the theory's supporters' postulate, is due to the cooling effects of aerosols and soot, which are also products of fossil fuel combustion. The models also predict more warming of a layer of the atmosphere (the troposphere) in the tropics than has been observed by satellite and radiosonde measurements, but AGW believers dispute the data showing that disparity. Proponents of the AGW theory believe man-made Carbon dioxide is responsible for floods, droughts, extreme weather, crop failures, species extinctions, spread of diseases, ocean coral bleaching, famines, and literally hundreds of other catastrophes. All these disasters will become more frequent and more severe as temperatures continue to rise, they say. Nothing less than large and rapid reductions in human emissions will save the planet from these catastrophic events(Sarmiento, *et. al.,* 1998).

2.7.2 Adaptive Management Model

The study also adopts Adaptive Management Model. Walters and Holling (1990) proposed three ways in which adaptive processes could be structured. First, there is an evolutionary or trial-and-error model (Holling 1978; Kusel *et al*., (1996) used the term incremental adaptive management and Hilborn (1992) referred to it as a reactive approach). Under such approaches, the results of external decisions and choices are used to frame subsequent decisions that, we hope, lead to improved results. In many ways, this form of adaptive management is reminiscent of muddling through, in which some learning inevitably results from whatever management experience is undertaken. There is no purposeful direction to it and one simply reaps whatever benefits derive from earlier experiences.

Second, there is the idea of passive adaptive management; Bormann *et al*., (1999) utilized the term sequential learning. In it, historical data are used to frame a single best approach along a linear path assumed to be correct (that is there is a belief that the underlying assumptions and antecedent conditions that were applicable earlier still prevail). This model applies a formal, rigorous, albeit post facto analysis to secondary data and experiences as a means of framing new choices, understanding or decisions.

Active adaptive management is a third model. It varies from other versions in its purposeful integration of experimentation into policy and management design and implementation (Kusel *et al*., 1996). In other words, policies and management activities are treated as experiments and opportunities for learning (Lee, 1993). Active adaptive management is designed to give data and feedback on the relative efficacy of alternative models and policies, rather than focusing on the search for the single best predictor. Bormann *et al.*, (1999) referred to active approaches as examples of parallel learning because they involve the design of suites of policies that can be directly and simultaneously compared and evaluated.

2.8 Conceptual Framework

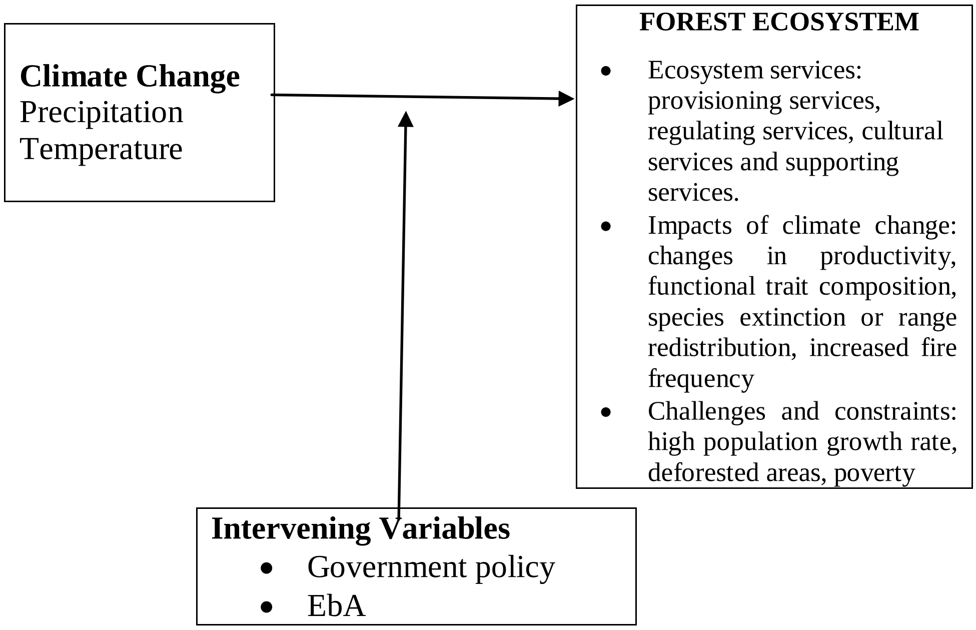

Figure 2.5: Conceptual Framework

Source: Researcher (2021)

The conceptual framework show independent variable that is climate change (variation of precipitation and temperature) that impacts the forest ecosystem in many ways. The impacts alters the forest ecosystem services that include provisioning, regulating, cultural and supporting services. The impacts of climate change can manifest itself in terms of productivity, functional trait composition, species extinction or range redistribution as well as in form of increased fire frequency. In mitigating the impacts of climate change, a number of challenges arise that include population growth, poverty among others. Also included in the conceptual framework are intervening variables that is government policy and Ecosystem-based Adaptation (EbA) initiatives.

CHAPTER THREE

RESEARCH METHODOLOGY

3.1 Introduction

This chapter presents research design and a description of the methods employed in this study. It further presents the methods employed in sampling, data collection and analytical methods used as well as a description of the study area.

3.2 Research Design

This study was descriptive and cross-sectional in design and it relied on a mixed methods methodology. According to Joppe (2000), a descriptive survey study helps to gather data at a particular point in time with the intention of describing the nature of existing conditions, identifying standards against which existing conditions can be compared and determining the relations that exist between specific events.

Mugenda (2010) recommends the design to collect data in order to answer questions concerning current status of the subject in the study. Surveys can be used for explaining or exploring the existing status of two or more variables at a given point in time. The design enables the researcher to have a wider coverage and comprehensive description of the observed characteristics and interrelationship in the target population (Creswell & Miller, 2005).

Descriptive survey design enables the researcher to collect original data for the purposes of describing and measuring the characteristics of a population, which is too large to be observed directly. The design was selected because it was very convenient in collecting substantial amount of views from respondents over a wide area using limited resources (Kombo and Tromp, 2006). Therefore, the variables that were studied were at their natural occurrence and not manipulated by the researcher. The survey method was appropriate because it is a self-report study, which requires the collection of quantifiable information from the sample. This involved collection of both quantitative and qualitative data. The study was concerned with the assessment of the impacts of Climate Change on Forest Ecosystem in Kenya with special emphasis to application of Ecosystem based Adaptation to Climate Change in Kakamega Tropical Rainforest ecosystem.

3.3 Research Philosophy

Scientific research philosophy is a method which, when applied, allows the scientists to generate ideas into knowledge in the context of research. The study was built on Pragmatist research philosophy which deals with the facts. It claims that the choice of research philosophy is mostly determined by the research problem. In this research philosophy, the practical results are considered important. In addition, pragmatism does not belong to any philosophical system and reality. Researchers have freedom of choice. They are “free” to choose the methods, techniques, and procedures that best meet their needs and scientific research aims. Pragmatists do not see the world as absolute unity. The truth is what is currently in action; it does not depend on the mind that is not subject to reality and the mind dualism.

3.4 Study Area

Kakamega forest is a mid-altitude tropical rainforest, the easternmost outlier of the Congo Basin forests. Its West African affinities are unique in Kenya, and the forest contains many species found nowhere else in the country. The forest lies in the Lake Victoria catchment, about 40 km north of Kisumu, and just east of the Nandi Escarpment that forms the edge of the central highlands.

Kakamega forest was first gazetted as Trust Forest in 1933, and two small Nature Reserves, Yala and Isecheno (totalling about 700 ha), were established within the Forest Reserve in 1967. In 1986, nearly 4,000 hectares of the northern portion of the forest, along with the adjacent 457 hectares Kisere Forest, were gazetted as a National Park. Kakamega Forest is an important catchment; the Isiukhu and Yala Rivers flow through the forest and gather tributaries from it. The terrain is undulating, with often steep-sided river valleys. The soils are well-drained, deep, heavily leached clay-loams and clays, of generally low fertility. Rainfall is approximately 2,001mm per year, decreasing from south to north, and apparently declining due to deforestation.

The study was conducted in Kakamega Tropical Rainforest and its environs that fall within Kakamega County in Western region of Kenya as shown in Plate 3.10. Kakamega town neighboring Kakamega forest has a population of 1,867,579 according to 2019 census. The average elevation of Kakamega is 1,535 meters above sea level. Kakamega County is Kenya's third most populous county after Nairobi and Kiambu (Kenya Census, 2019). Local inhabitants are mostly the Luhya ethnic community, whose economic activity is mainly farming. Kakamega County serves as the headquarters of Kenya's largest sugar producing firm, Mumias Sugar, located in Mumias town.

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 26^0C and a mean minimum of 11^0C. 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, while the second stratum is the middle height tree layer (18-27m) and comprised of trees, climbers and woody lianas. The third canopy layer has short trees (14-17meters).

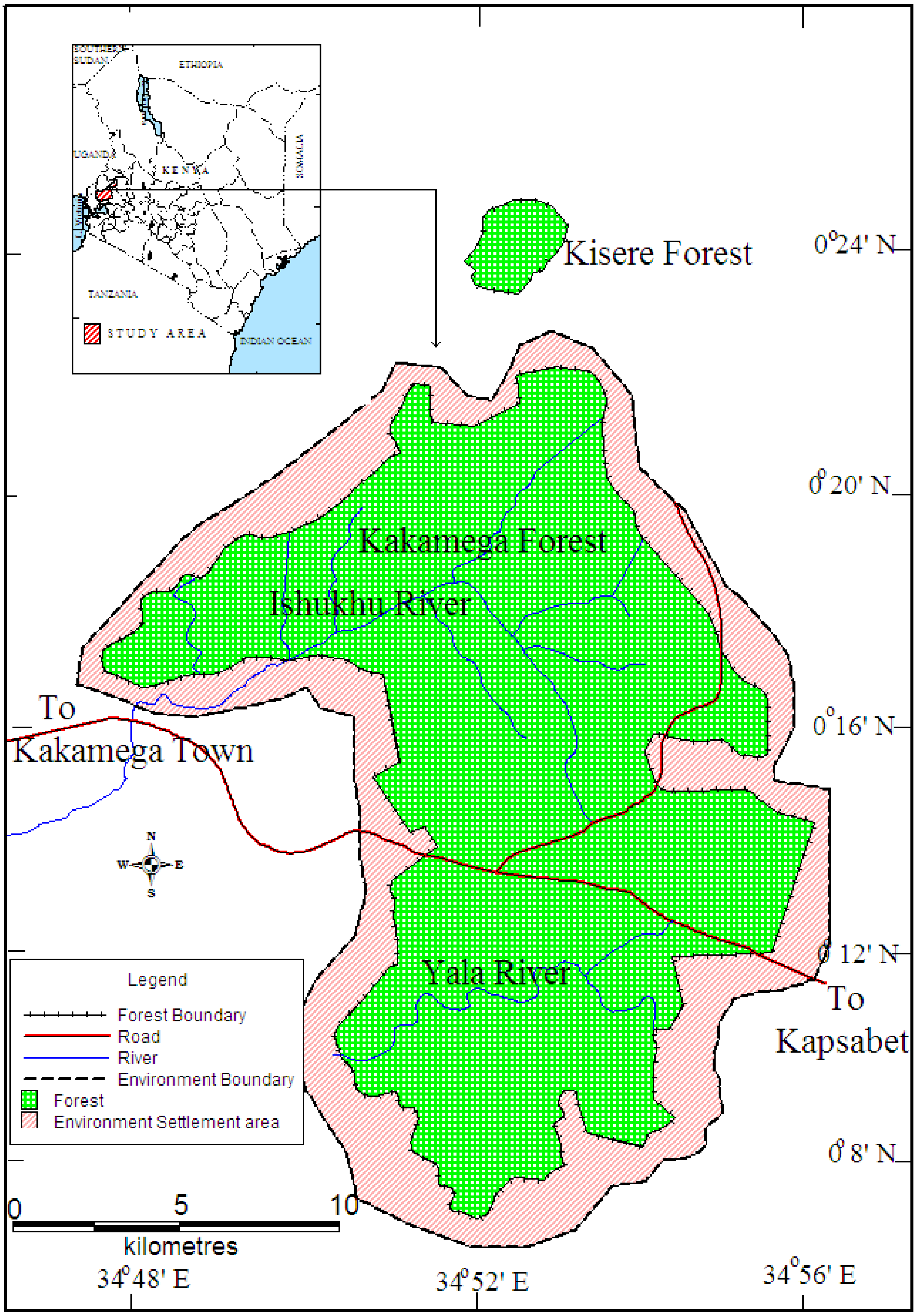

Plate 3.1: Map of Kakamega Tropical Rainforest Ecosystem and its Environment.

Source: Moi University, Department of Geography and Environmental Studies GIS Lab (2021).

3.5 Study Population

Population refers to an entire group of individuals, events or objects having a common observable characteristic and a sample is a smaller group obtained from the accessible population ((Mugenda, 2008). As a first step in the data collection stage of every survey, the target population needs to be identified. This study was undertaken in the rural area around Kakamega Tropical Rainforest. The survey units were households living up to 10 km from the forest edge and officers from Kenya Forest Service within Kakamega County.

3.6 Sample Size and Sampling Procedures

Sampling is a technique of selecting individual members or a subset of the population to make statistical inferences from them and estimate characteristics of the whole population. Orodho (2005) defines a sample as a set of respondents (people) selected from a large population for the purpose of a survey for a study. Sampling is the act, process or technique of selecting a suitable sample or a representative part of a population for the purpose of determining characteristics of the whole population (Kombo and Tromp, 2006).

The respondents from the adjacent forest community were selected on the basis of the human settlement pattern in the Kakamega forest region and the distance of homesteads from the forest boundary. Significant interactions of the community with the forest exist within 10 kilometers from the forest boundary. Thus, households were drawn from the settlement regions. A census of households carried out with the help of administrative village heads and other local leaders generated a sampling frame consisting of approximately 345 households residing within approximately 10km radius of the forest.

The selection of households was done at various distances of 3 kilometers; 3 to 6 kilometers and 6 to 10 kilometers from the forest boundary in the settlement areas using Stratified random sampling subsequently, a sample size of 184 respondents was obtained by the guidance of Krejcie and Morgan table of 1970. Efforts were made to map out both male- and female-headed households in each stratum during the reconnaissance survey. All female-headed households identified in the three strata were purposively sampled to ensure adequacy in female gender sample representation. However, male-headed households were selected for a household survey through simple random sampling.

Forest Service officers were purposefully selected based on their knowledge in conservation, impact of climate change on the forest and development issues in the region as well as their geographical distribution within the forest boundary.

Table 3.1: ***Sampling Frame***

RESPONDENTS	TOTAL	SAMPLE SIZE	%
Households	345	184	53
Forest Officers	53	20	37.7
Total	**253**	**204**	

Source: Researcher (2021)

3.7Data Collection Instruments

Data for this research was collected from both primary and secondary sources. Researchers prefer using methods that provide high accuracy, generalizability and explanatory power, with low cost, rapid speed and maximum management demands and administrative convenience (Orodho and Kombo, 2005). This study used questionnaires and interviews as main instruments of data collection. The instruments contained questions dealing with the impact of climate change on forest ecosystems in Kenya with special emphasis on application of Ecosystem-based Adaptation to climate change in Kakamega Tropical Rainforest ecosystem of Kakamega County, Kenya.

3.7.1 Questionnaire

The questionnaire contained both open and closed ended questions for residents (Appendix I). A structured questionnaire was used to collect data within a short time (Orodho, 2005).

The quantitative tool was administered to a sample of 184 respondents enlisted from the general population, to determine ecosystem services of Kakamega Tropical rainforest. The tool was administered to the general population to elicit the impacts of climate change on forest ecosystem.

This tool was therefore used to draw information from men and women about EbA to climate change and challenges facing EbA implementation. The questionnaire was undoubtedly the best survey method of collecting quantitative data from the general population. A researcher administered semi-structured questionnaire was employed (See appendix I).

3.7.2 Interviews

An interview schedule was used to collect qualitative in-depth data. The interviews provided the researcher with greater opportunity to explain the purpose of the study (Amin, 2003). The interviews were administered to the Kenya Forest Service officers in charge of the area. Interviewing gave an opportunity to supplement data elicited by questionnaires thus providing more information to the study. It served as a follow-up to supplement and eliminate the shortfalls of the questionnaire.

According to Mugenda and Mugenda (2010), interviews allow for the free interaction, honest conversation and probing questions for higher response. It is difficult for a respondent to completely refuse to answer questions or ignore the interviewer. The designed structured interview schedule was moderated by the help of colleagues and the two supervisors (See appendix II).

Below is a matrix depicting data collection methods and variables of the study:

Method	**Research question**	**Key variables**
Questionnaire	1. What are the spatial and temporal characteristics of climate change in Kakamega tropical rainforest 2. What are the forest ecosystem services of Kakamega Tropical Rainforest of Kakamega County, Kenya? 3. What are the impacts of climate change on Kakamega Tropical Rainforest Ecosystem? 4. Evaluate Ecosystem-based Adaptation to climate change in Kakamega Tropical Rainforest. 5. What are the challenges and constraints facing implementation of EbA initiatives in Kakamega Tropical Rainforest Ecosystem.	-Spatial and temporal characteristics of climate change -Ecosystem services, -Impacts of climate change on Kakamega Tropical Rainforest Ecosystem, -Ecosystem-based Adaptation to climate change -Challenges and constraints
Interviews	1. What are the spatial and temporal characteristics of climate change in Kakamega tropical rainforest 2. What are the forest ecosystem services of Kakamega Tropical Rainforest of Kakamega County, Kenya? 3. What are the impacts of climate change on Kakamega Tropical Rainforest Ecosystem? 4. Evaluate Ecosystem-based Adaptation to climate change in Kakamega Tropical Rainforest. 5. What are the challenges and constraints facing implementation of EbA initiatives in Kakamega Tropical Rainforest Ecosystem.	-Spatial and temporal characteristics of climate change -Forest ecosystem services -Impacts of climate change -EbA -Challenges and constraints

Source: Researcher (2020)

3.8 Piloting

Kombo and Tromp (2006) argue that a pilot study helps to test the feasibility of the study techniques and to perfect the questionnaire and interview schedule, concepts and wordings. It was carried out three weeks before the actual data collection for the study. Piloting was done to establish whether the instruments could be used to collect relevant data, identify any problems likely to occur at the time of actual data collection process and to also check whether the instructions in the questionnaires were understood by the respondents (Plate 3.2 and 3.3). The items were revised with the help of the researcher's supervisors from the Department of Geography, Moi University.

To determine the reliability and validity, the questionnaire and interview schedule were piloted among 20 respondents and 5 Key informants respectively among the residents of Kaimosi Tropical Rainforest that borders Kakamega Tropical Rainforest.

Plate 3.2: Researcher with a resource person at the Grassland section of Isecheno at Kakamega Tropical Rainforest Ecosystem (Source: Researcher, 2020)

Plate 3.3: Kenya Forest Service Western Conservancy (Source: Researcher, 2020)

From Left Bosibori-A research Assistant, Prof Omondi-Supervisor, Aseta-Researcher and Koros-Research Assistant at the Conservator's office after an Interview.

3.9 Validity and Reliability of Research Instruments

The results of the pilot study were used to test the validity and reliability of the research tools.

3.9.1 Validity

This is how accurate a tool or an instrument is in obtaining the data that it intends to collect (Kerlinger, 1983). This relates to content validity. Construct validity refers to the way questions or items of the tool measures the skills or characteristics that are intended to be measured by an instrument. The construct validity of research instrument was ascertained by discussing with the supervisors and experts from the Department of Geography, Moi University. The researcher was guided and advised accordingly after scrutinizing and checking on the irrelevant items and technical mistakes. Through their wise advice, the questionnaire was revised to suit the study.

3.9.2 Reliability of the Research Instrument

Reliability refers to the ability of the instrument to give same responses after repeated administration (Mugenda and Mugenda, 2010). Orodho (2005) defines reliability as the degree of consistency that an instrument or procedure demonstrates. In order to ascertain the reliability, the test–retest method was used in administration of the data collection tools. The administration of the tools was carried out on two occasions within a period of two weeks with subjects from Kakamega County. Reliability was determined by correlating two administrations using Pearson's product-moment correlation coefficient.

The Pearson Product Moment Correlation Coefficient was adopted for the study because it is a measure of correlation that shows the type and strength of the relationship between two variables under study (Orodho, 2003). Orodho further argues that if the coefficient is computed at + 0.5 then the questionnaire is deemed reliable. In this case the researcher considered the instrument reliable if it attains a reliability coefficient of 0.6.

3.10Data Collection Procedures

A variety of data collection methods were incorporated to collect both quantitative and qualitative data from both primary and secondary sources. The researcher collected data in three phases; the first phase involved conducting a reconnaissance trip to the study area. Piloting was also done during this phase and the instruments refined. In the second phase, the researcher sort permission from the relevant authorities to conduct the study. The researcher applied for a research permit to the National Commission for Science, Technology and Innovation. The third phase was the actual collection of data, the researcher booked an appointment with the relevant subjects to be interviewed and distributed the interview schedules with the aid of three research assistants.

Out of the 184 members of the households who were selected to participate in the study, 119 returned the questionnaires. On the other hand, out of the 20 selected forest officers all of them (100%) returned the questionnaires. The return rates were considered appropriate to go on with the analysis. The data collected through interview schedules was coded before being analyzed.

Past meteorological data on rainfall and temperature parameters was sourced from Kenya Meteorological Department (Sichirai station) located at 0.28° N 34.75°. Data included average monthly rainfall for the years between 1967 and 2020, as well as minimum and maximum temperatures covering the same period to support analysis.

3.11 Data Analysis

Based on the data evaluation instruments, quantitative and qualitative data analysis techniques were utilized. Data from questionnaires were analyzed in frequencies, means and percentages using the Statistical Package for Social Sciences (SPSS version 23.0). Qualitative data from the interviews were analyzed in themes and categories identifying similarities and differences that emerge. The SPSS was used to generate frequency distribution tables. A descriptive statistical method was used and adopted to calculate the percentages and means. Rainfall and temperature trends were analysed using Mann–Kendall tests and Sen's slope estimator. The Mann–Kendall (MK) test, a non-parametric test, was considered the most ideal to determine rainfall and temperatures trends over time. This test was applied at 95 per cent confidence levels and used as described by Sneyers (1990). Positive (+ve) values from the results indicated an increase over time while negative (−ve) values point to a decreasing trend. MK detects non-linear trends but is limited in showing the magnitudes of significant trends (Babar and Ramesh, 2013). Thus, Sen's slope estimator, also a non-parametric test, was used to detect magnitudes of climatic trends for both rainfall and temperatures.

3.12 Ethical Considerations

The researcher provided the respondents with information on the purpose and duration of the study. The researcher assured the respondents of their privacy and confidentiality of the information they gave. The researcher also ensured that all participants remain anonymous in the study by asking them not to write their names in the questionnaires. Respondents were assured of their dignity being kept and that they will not suffer either physical or psychological harm during and after the study. The researcher also debriefed the respondents on the findings after the study (Campell, 2002).

CHAPTER FOUR

DATA ANALYSIS, RESULTS AND DISCUSSIONS

4.0 Introduction

This chapter deals with data analysis, presentation, interpretation and discussion of findings. This study assessed the impact of climate change on forest ecosystems in Kenya with special emphasis on application of EbA to climate change in Kakamega tropical rainforest ecosystem. The data collected was analyzed using both descriptive and inferential statistics. This chapter presents the results of the analysis.

4.1 Background Information of Members of Households and Forest Officers

The background information of the members of the households and forest officers centered around seven aspects that the researcher felt were important to understand, as this would affect the responses they gave. These aspects were: gender, distance from forest, age, highest education level, occupation, years of stay and monthly income. The results are summarized in table 4.1.

Table 4.1: ***Background information of members of the households***

Characteristic	Household Members F	Household Members %	Forest Officers F	Forest Officers %
Gender				
Male	74	62.2	15	75
Female	45	37.8	5	25
Total	**119**	**100**	**20**	**100**
Distance from the forest**				
0.1-3 km	44	37.0	5	25
3.0-6 km	45	37.8	11	55
6.0-10 km	30	25.2	4	20
Total	**119**	**100**	**20**	**100**
Age				
6-15 years	7	5.9	-	-
16-25 years	16	13.4	-	-
26-35 years	20	16.8	01	5
36-45 years	52	43.7	10	50
46 years and above	24	20.2	09	45
Total	**119**	**100.0**	**20**	**100**
Highest Education level				
Primary	24	20.2	-	-
Secondary	47	39.5	-	-
Tertiary	28	23.5	05	25
Others	20	16.8	15	75
Total	**119**	**100**	**20**	**100**
Occupation				
Peasant	62	52.1	-	-
Civil servant	18	15.1	20	100
Business person	20	16.8	-	-
Large scale farmer	19	16.0	-	-
Total	**119**	**100**	**20**	**100**
Years of Stay				
1-5 years	14	11.8	3	15
6-10 years	54	45.4	8	40
Over 10 years	51	42.9	6	30
Total	**119**	**100**	3	15
			20	**100**
Monthly Income				
No response	**119**	**100**	**20**	**100**

Source: Researcher (2021)

When the residents were asked which location they came from, a higher percentage, 9.2% (11) indicated that they come from Kambiri location, all the other nineteen locations had representatives. Ivakate location had the least members at 1.7% (2) as shown in Figure 4.1.

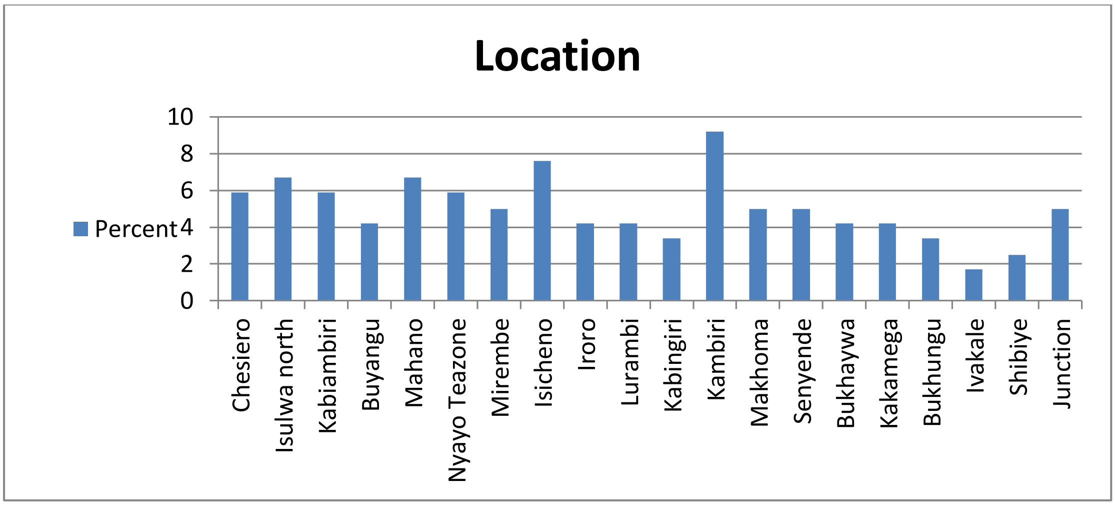

Figure 4.1: Locations

Source: Researcher (2021)

On issues of gender the male were the majority at 74(62.2%) and the female were 45(37.8%) as shown in Figure 4.2.

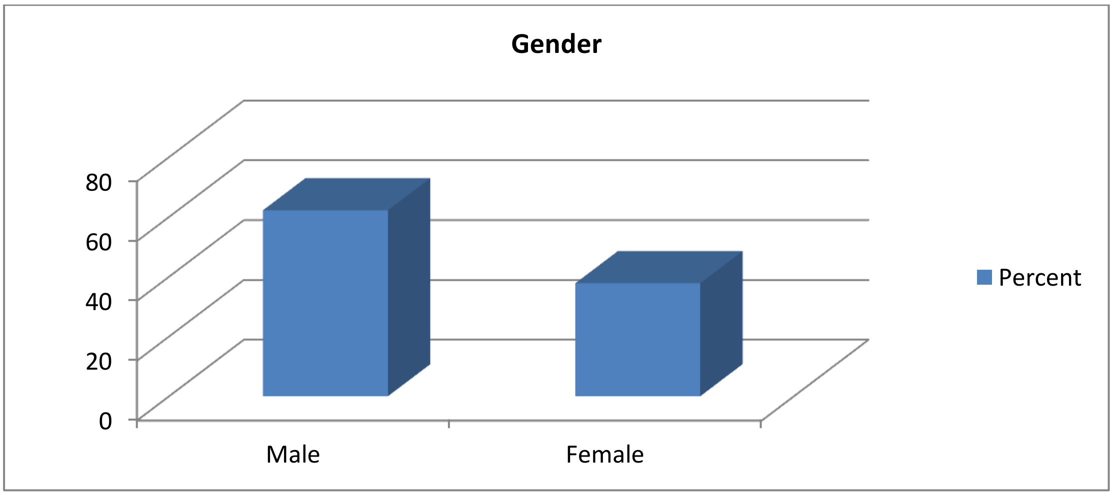

Figure 4.2: Gender

Source: Researcher (2021)

When the residents were asked how far they stay from the forest, a majority 45 (37.8%) indicated that they stayed between 3.0 - 6 km, almost a similar number 44 (37.0%) indicated that they stayed 0.1 – 3.0 Kms away from the forest while 30

(25.2%). This shows that all the residents stayed less than 10 kilometers from the forest.

When asked about their age, the majority were aged between 36-45 years 52 (43.7%) followed by those aged 46 years and above (20.2%) followed by those between 26-35 years (16.8%), then followed by those between 16-25 years (13.4%), and the least were those aged between 6-15 years (5.9%) as indicated in Table 4.1. This shows that the majority of the forest inhabitants are in their productive age at 52(43.7%) as indicated in Table 4.1. This shows that the majority of the forest inhabitants are in their productive age group of 36-45 years of age.

When the respondents were asked about their highest level of education, the majority 47(39.5%) indicated that they had secondary level of education, followed by those who had tertiary level of education who were 28(23.5%) in number, then those who had attained primary level of education 24 (20.2%) as indicated in Table 4.1 and Figure 4.3.

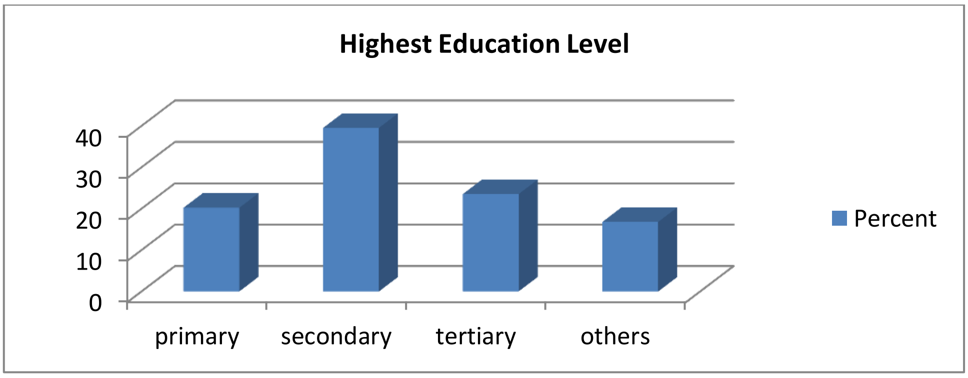

Figure 4.3: Educational Levels
Source: Researcher (2021)

When the respondents were asked about their occupation, a majority 62(52.1%) indicated that they were peasants, 20(16.8%) were business persons, 19 (16.0%) were large scale farmers while the least number at 18(15.1%) were civil servants as indicated in Figure 4.4. This shows that the majority who are peasants are likely to interfere with the forest ecosystem during their farming activities.

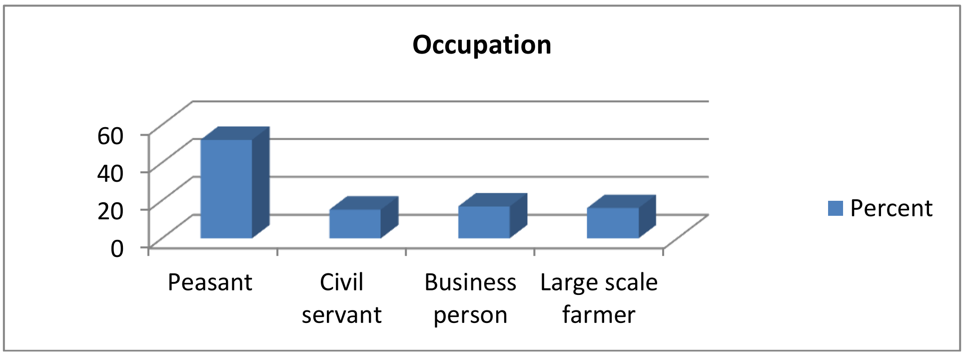

Figure 4.4: Occupation

Source: Researcher (2021)

All the respondents 119(100%) did not indicate their monthly income as shown in Figure 4.5. This is an indication that most people are usually reluctant or unwilling to share their personal matters such as incomes.

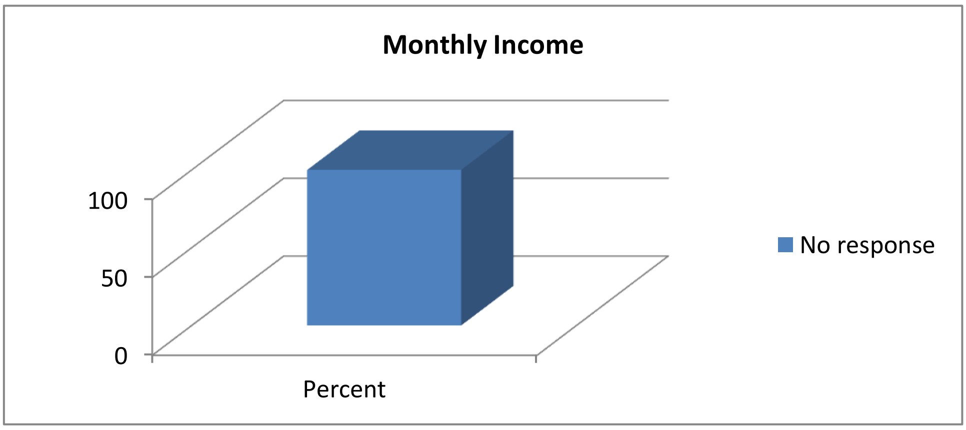

Figure 4.5: Monthly Income

Source: Researcher (2021)

When asked about how many years they have stayed in the area, a majority 54(45.4%) has stayed between 6-10 years, then followed by those who had stayed over 10 years who were 51(42.9%) and those who had stayed for periods between 1-5 years, numbering 14(11.8%) as indicated in Figure 4.6. This shows that the majority of the people stayed in the area long enough to have had experienced negative impact on the forest ecosystem.

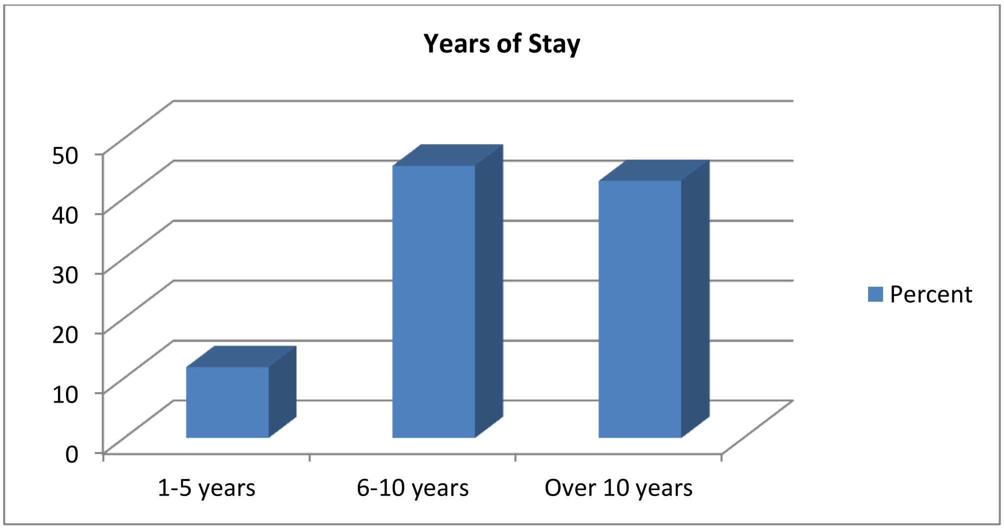

Figure 4.6: Years of Stay
Source: Researcher (2021)

4.1.1 Background Information on Forest Officers

Regarding the gender of the respondents, a majority 15(75%) were male while only 5(25%) were female.

There was one forest officer from each of the twenty locations as shown in Table 4.1. When the forest officers were asked how far they stayed from the forest a majority 11 (55%) indicated that they stayed between a range of 3.0 – 6.0 kilometers from the forest and 5(25%) indicated that they stayed between 0.1-3.0 Kilometers from the forest while 4(20%) stayed between 6-10 kilometers. This shows that all the officers were staying at less than 10 kilometers from the forest which is very close to the forest.

When asked about their age, half of them, 10(50%) were aged between 36-45 years of age, followed closely with those aged 46 years and above who were 9(45%) and only 1(5%) was aged between 26-35 years of age.

When the forest officers were asked about their highest level of education attained those with other levels of education apart from tertiary education were the majority 15(75%) while only 5(25%) had tertiary level of education. On the work they do, all the 20 (100%) forest officers indicated that they were civil servants.

The forest officers were also asked on the length of stay they have had in the area, a majority 7(40%) had stayed for between 6-10 years, followed by those who had stayed for over 10 years who were 6(30%) in number, then followed by those who had stayed for over 10 years and those who have stayed for less than 1 year who were both at 3(15%). This shows that many of the forest officers have stayed in the area long enough to give valid opinions about the occurrences taking place in the forest.

4.2 Spatial and Temporal Characteristics of Climate Change in Kakamega Tropical Rainforest

The first objective of this study was to establish the spatial and temporal characteristics of climate change in Kakamega Tropical Rainforest.

Temperature trend analyses represent statistically significant trends for the period of 1967-2020. Results reveal a warming trend for both mean annual maximum temperatures and mean annual minimum temperatures by 0.04°C/year and 0.02°C/year, respectively. Moreover, analysis of annual precipitation (1967-2020) indicated an increase of 0.068 mm/year; however, the mean monthly rainfall showed a decreasing trend.

4.2.1 Mean monthly rainfall variability.

Observations of the behaviour of mean monthly rainfall for the period 1967-2020 indicate a rainy season in the months of April (255 mm) and May (257 mm). The precipitation then slightly subsides in June before picking up again in July with August registering higher amounts (222 mm). December, January and February recorded the least amount of rainfall at 91, 68 and 92 mm, respectively. Generally, the March-April-May (MAM) peaks were stronger than the October-November-December (OND) peaks. According to Nicholson (2017), MAM constitutes the long rainy season, while OND covers the short rain season in most parts of equatorial Eastern Africa. This coincides with crossing the inter tropical convergence zone along the equator in south-north, before taking the north-south migration (Camberlin and Philippon, 2002).

MK tests for mean monthly rainfall (1969-2020) indicate positive trends in January, March, April, September, October, November and December.

However, increase of rainfall both in October and November were declared significant at $\alpha = 0.01$. The remaining calendar months displayed trends that were not significant, with the exception of July, which was significant at 95 per cent level. Sen's slope ranged between - 0.543 and 0.761 for the same climatological period. Results on the magnitude of change are largely negative, with the month of May indicating a decline in rainfall by 0.543 mm/year. On the same note, the magnitude of change was highly positive in November implying an increased precipitation by 0.0761 mm/year.

4.2.2 Mean annual rainfall variability.

Notable peaks of rainfalls were experienced between 1968 and 1983, whereas significant dips were emerged in 1988 and 2012. While coefficient of rainfall variation (R^2 linear = 0.193) was low and probably insignificant, the cumulative effects of rainfall variability are expected to advance in future with less predictability.

The MK test for annual precipitation for the same period was found to increase by 0.068 mm/year, probably due to increased frequency of hailstorms in the region during previous years. Lau and Wu (2007) asserted that satellite-based studies conducted in the tropics during 1979-2003 reported an increase in the occurrence of heavy rain-related events.

4.2.3 Mean monthly temperature variability

Maximum and minimum temperatures in Kakamega County both escalate from January to April while they are at their lowest from July to September. It is important to note that onset of the long rainy season is always expected towards the end of March and into the month of April. Given that April comes immediately after a dry spell (January-March), temperatures in the region would still be expected to be higher. February was the hottest (31°C) month during the climatological period while September was the coolest at 13.6°C. The three-month period July, August and September recorded the lowest minimum temperatures, while April had the highest minimum temperature of 15.2°C. These findings concur with observations made by Barasa *et al.* (2015) on temperature variations in the region. Generally, it can be deduced that temperature trends on both scales (maximum and minimum) increase/decrease almost at the same time range.

4.2.4 Mean annual temperature variability

There was variability in both annual mean maximum and minimum temperatures, with the highest values recorded in 2009 and 2014. The lowest mean maximum temperatures of 19.9°C, 20.4°C and 22.6°C were recorded in 1999, 1991 and 1994, respectively. Similarly, mean minimum temperatures were lowest (10.4°C) in 1999. This coincides with the lowest maximum temperatures recorded for the same year, marking 1999 as the coolest year for the entire period under examination. However, the highest minimum temperatures (15°C) occurred in 2010. The MK test for maximum and minimum temperatures indicates positive trends, suggesting that temperatures have been on the rise for the climatological period 1980-2020.

With regard to maximum temperatures, the rise was found to be significant at $\alpha = 0.05$ for January, February, September, November and December. The magnitude of the temperature increase as represented by Sen's slope was 0.019°C/year for minimum temperatures and 0.037°C/year for maximum temperatures. The findings indicate that global warming is being felt in the region, echoing Mulinya *et al.* (2016), who observed similar characteristics in temperature trends. The knowledge of the significance of temperature variations is pertinent in the understanding of climate change.

4.2.5 Perceptions of climate variability

The views collected from study participants as regards to climate variability were vital for comparison with meteorological data. In general, the majority of respondents were aware of climate variability and would explain their experiences using observable features, such as delayed rainfall, rising temperatures and prolonged drought spells over the past 50 years and more.

Many respondents felt that rainfall patterns were uncertain, probably due to large inter-annual fluctuations in rainfall quantities over the years. These perceptions reinforce our findings on the meteorological data analysis on temperatures and rainfall patterns. In the same vein, Simelton *et al.* (2013) suggested that locals' perspectives of climate variability play a significant role in addressing climate change impact and adaptation of Kakamega forest ecosystem.

In a bid to also to further a certain this scenario, several questions were put forward. They included finding out their understanding of climate change. The results are summarized in Table 4.2.

Table 4.2: ***Spatial and Temporal Characteristics of Climate Change in Kakamega Tropical Rainforest***

ITEM	CATEGORY	Agreed		Undecided		Disagreed		Total	
		F	**%**	**F**	**%**	**F**	**%**	**F**	**%**
Climate change is very extreme temperatures	HM	96	80.7	4	3.4	19	15.9	119	100
	FO	20	100	-	-	-	-	20	100
Climate change is very extreme precipitation	HM	88	73.9	13	10.9	18	15.2	119	100
	FO	20	100	-	-	-	-	20	100
Climate change is both extreme temperatures and precipitation	HM	97	81.5	10	8.4	12	10.1	119	100
	FO	14	70	6	30	-	-	20	100
Shift in the rainy and dry season is a visible change in climate	HM	99	83.2	5	4.2	15	12.6	119	100
	FO	20	100	-	-	-	-	20	100
Drought is a visible change in climate	HM	77	64.7	10	8.4	32	26.9	119	100
	FO	19	95	1	5.0	-	-	20	100
Intense rainfall is a visible change in climate	HM	88	73.9	15	12.6	16	13.5	119	100
	FO	14	70	6	30	-	-	20	100
Less rainfall is a visible change in climate	HM	92	77.3	18	15.1	9	7.5	119	100
	FO	18	90	2	10	-	-	20	100

KEY: HM-Household members.FO-Forest Officers.

Source: Researcher (2021)

The members of the households were asked what they perceived to be climate change. Among those who viewed climate change as very extreme temperatures, majority of them at 96(80.7%) agreed, 19 (16%) disagreed, while only 4(3.4%) were undecided as indicated in Figure 4.7.This concurs with Boon and Ahenkan(2011) who argues that past studies have demonstrated how forested areas and their surroundings have experienced general reductions in precipitation and increases in temperature over time.

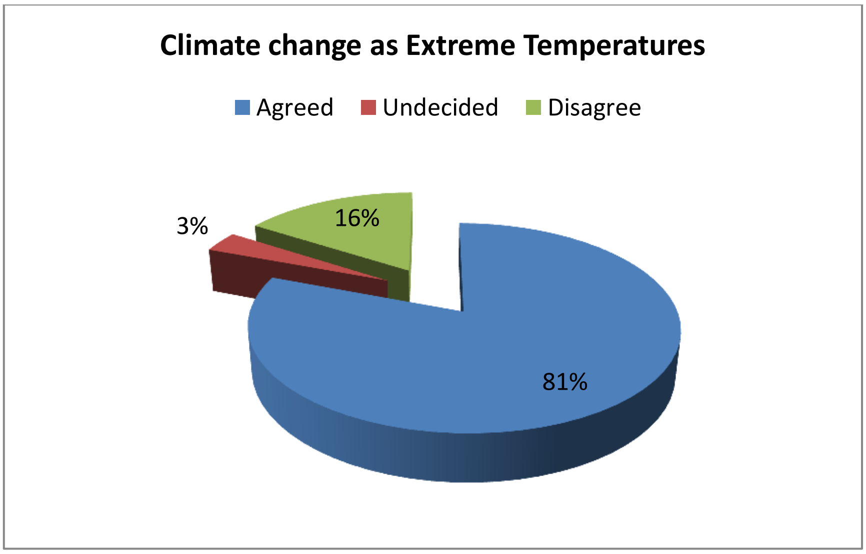

Figure 4.7: Climate Change as Extreme Temperatures

Source: Researcher (2021)

Among those who viewed climate change as very extreme precipitation, a majority of them at 88(74%) agreed, 18(15.2%) disagreed while a few 13(10.9%) were undecided as shown in Figure 4.8.

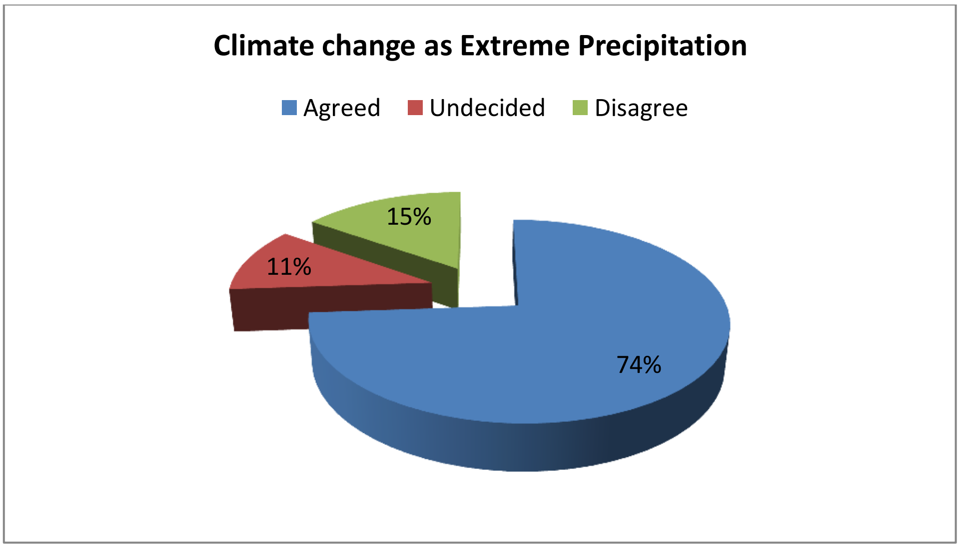

Figure 4.8: Climate Change as Extreme Precipitation

Source: Researcher (2021)

Among those who viewed climate change as both very extreme temperatures and precipitation, a majority of them again at 97(81.5%) agreed, 12(10.1%) disagreed while 10 (8.4%) were undecided as shown in Figure 4.9. These shows that a majority of the members of the households' respondents viewed climate change as extreme changes in both temperatures and precipitation.

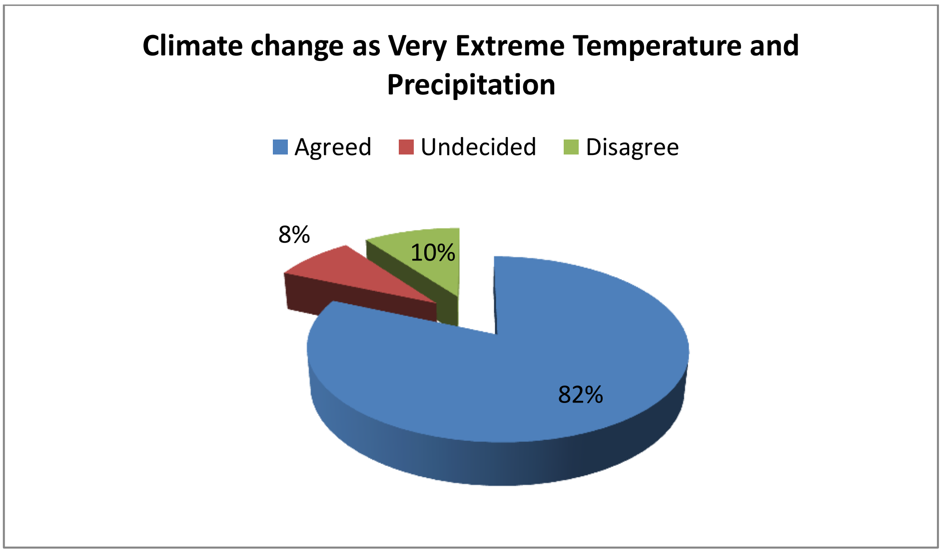

Figure 4.9: Climate Change as Very Extreme Temperature and Precipitation
Source: Researcher (2021)

The views on the same question posed to forest officers were not different. All 20(100%) of the forest officers agreed that climate change was having very extreme temperatures. On the other hand, all the 20(100%) of the forest officers agreed that climate change was having very extreme precipitation. On whether climate change was having both extreme temperature and precipitation a majority at 14(70%) of the forest officers indeed agreed, while 6(30%) were undecided on the issue.

This shows that both the members of the households and the forest officers were of the view that climate change was having extreme temperature and precipitation, views supported by Safeeqet *et al.*,(2013) who argues that at smaller spatial scales minimum temperature on the island of Oahu in Hawaii, USA have an average increase of 0.17 degrees Celsius per decade and the statewide average warming for Hawaii is 0.2 degrees Celsius per decade since 1975 (Giambelluca *et al*., 2008).The complexity of precipitation trends is even greater when comparing changes at smaller spatial scales, as significant differences in annual precipitation trends have been observed across three islands in the Hawaiian Archipelago (Chen and Chu, 2014).

When asked if the members of the households have ever witnessed climate change, a majority at 83(69.7%) agreed while a few at 36(30.3%) disagreed. When the same question was posed to the forest officers similar results were obtained with a majority 12(60%) indicating agreed while 8(40%) disagreed (See Figure 4.10). This shows that climate change is a normal observable occurrence that can be witnessed by people living near the forest. This is in agreement with the IPCC (2013) views that changes in temperature have been extensively studied and are well understood across a wide range of temporal and spatial scales.

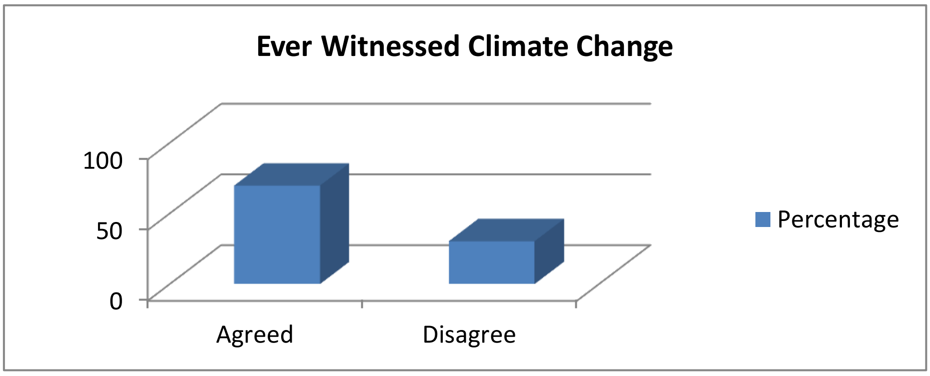

Figure 4.10: Ever Witnessed Climate Change
Source: Researcher (2021)

When the members of the households were asked to indicate the spatial and temporal characteristic of climate change in Kakamega Tropical Rainforest, those who viewed that as a shift in the rainy and dry season, a majority at 99(83.2%) agreed while only a few at 15 (12.6%) disagreed and only 5(4.2%) were undecided as shown in Figure 4.11. On the other hand among the forest officers, all the 20(100%) agreed that it was indeed a shift in the rainy and dry season.

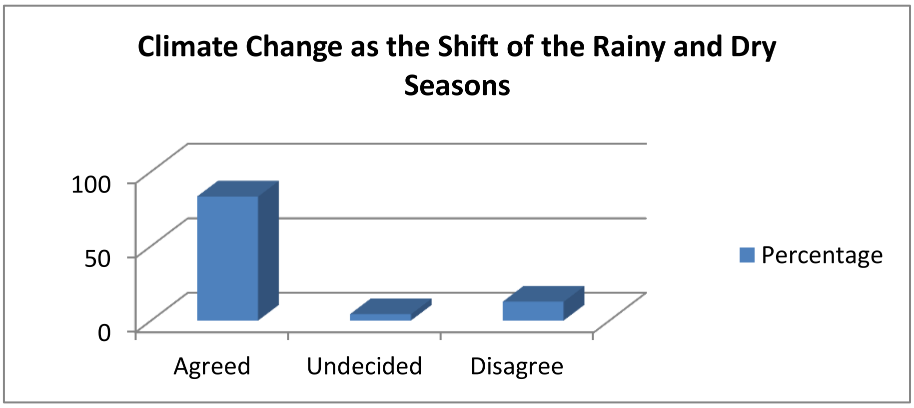

Figure 4.11: Climate Change as the Shift of the Rainy and Dry Seasons

Source: Researcher (2021)

The members of the households who felt that the spatial and temporal characteristics of climate change was drought, a majority at 77(64.7%) agreed, 32(26.9%) disagreed while only 10 (8.4%) were undecided as shown in Figure 4.12. On the other hand, among the forest officers', majority at 19(95%) agreed while only 1(5%) was undecided. This shows that the majority of the household's respondents and forest officers' respondents view drought as one of the consequences of climate change. These views are supported by Goosse *et al.* (2010) who argues that climate change includes the region's general pattern of weather conditions, seasons and weather extremes like hurricanes, droughts, or rainy periods.

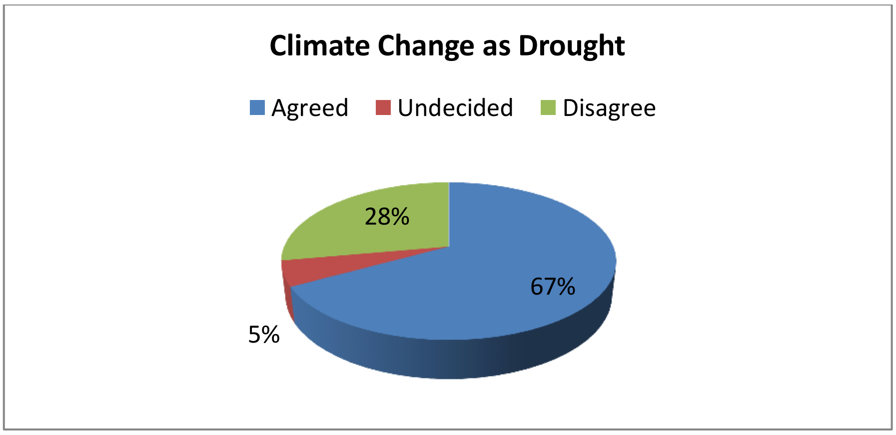

Figure 4.12: Climate Change as Drought

Source: Researcher (2021)

The other variable that the members of the households were supposed to respond to was if they felt that the spatial and temporal characteristics of climate change was intense rainfall. A majority at 88(73.9%) agreed, 16(13.5%) disagreed, while 15 (12.6%) were undecided as indicated in Figure 4.13. On the other hand, a majority of the forest officers at 14(70%) agreed that it was intense rainfall while the rest 6(30%) were undecided. This shows that majority of the members of the household and forest officers agreed that intense rainfall was part of the effect of climate change as supported by Goosse et al., (2010).

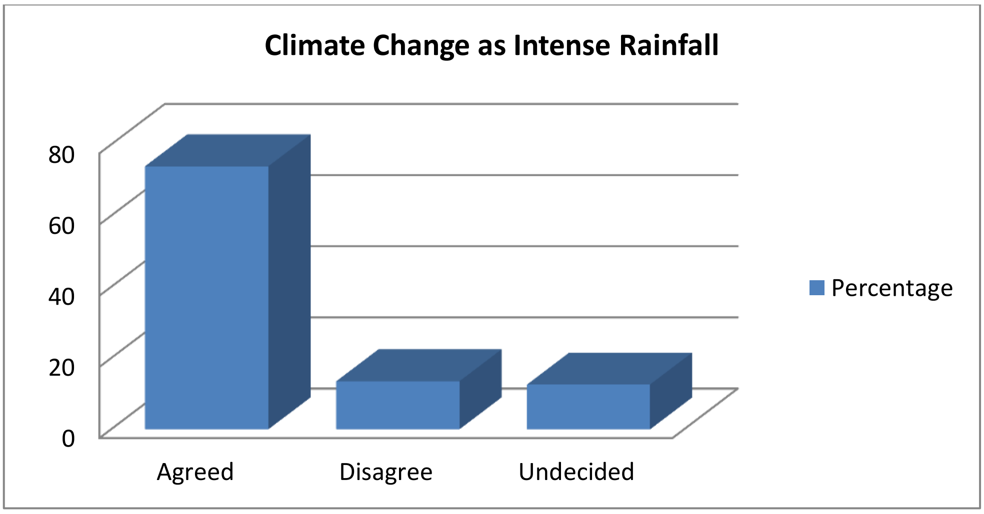

Figure 4.13: Climate Change as Intense Rainfall
Source: Researcher (2021)

When asked whether the spatial and temporal characteristics of climate change was less rainfall, a majority at 92(77.3%) of the members of the household agreed, 9(7.5%) disagreed while 18(15.1%) were undecided as can be seen in Figure 4.14. On the other hand, a majority at 18(90%) of the forest officers agreed, while only 2(10%) were undecided. This agrees with the views of Goosse *et al.* (2010) about less rainfall being a consequence of climate change.

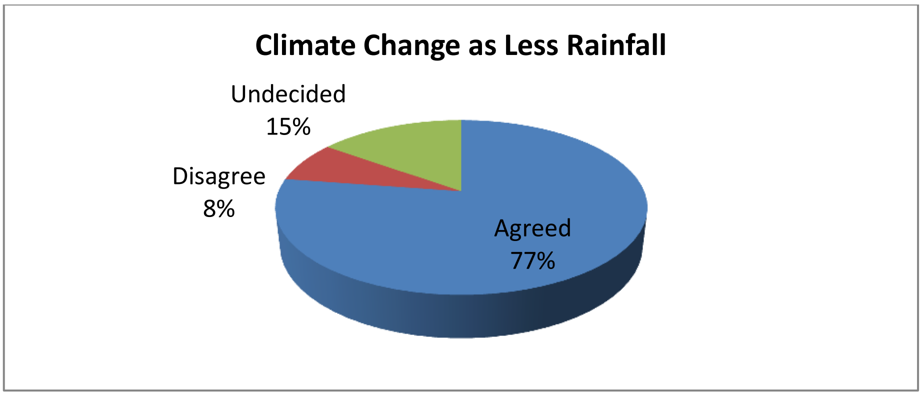

Figure 4.14: Climate Change as Less Rainfall

Source: Researcher (2021)

4.3 Ecosystem Services of Kakamega Tropical Rainforest.

The second objective of this study was to analyze the ecosystem services of Kakamega Tropical Rainforest. In order to answer the question related to this objective, the researcher sought some responses from both the members of the households as well as the forest officers in relation to this question as shown in Table 4.3.

Table 4.3: ***Ecosystem Services of Kakamega Tropical Rainforest*.**

ITEM	Category	Agreed		Undecided		Disagreed		Total	
		F	%	F	%	F	%	F	%
Ecosystem services of the forest is source of Timber	HM	16	31.4	13	10.9	90	75.7	119	100
	FO	20	100	-	-	-	-	20	100
Ecosystem services of the Forest is source Firewood	HM	100	84	11	9.2	8	6.8	119	100
	FO	17	85	3	15	-	-	20	100
Ecosystem services of the Forest is source of Herbal Medicine	HM	90	75.7	15	12.6	14	11.7	119	100
	FO	16	80	4	20	-	-	20	100
Ecosystem services of The Forest is source of Fodder for Livestock	HM	89	74.8	10	8.4	20	16.8	119	100
	FO	18	90	2	10	-	-	20	100
Ecosystem services of The Forest is source of Food	HM	26	21.8	18	15.1	75	63.1	119	100
	FO	17	85	3	15	-	-	20	100
Ecosystem services of the Forest prevents Storms	HM	81	68.1	4	3.4	34	28.5	119	100
	FO	20	100	-	-	-	-	20	100
Ecosystem services of the forest helps to Control Floods	HM	89	74.8	14	11.8	16	13.4	119	100
	FO	19	95	1	5	-	-	20	100
Ecosystem services of the forest helps in Cloud Formation	HM	98	82.4	11	9.2	10	8.4	119	100
	FO	20	100	-	-	-	-	20	100
Ecosystem Services of the forest helps in Greenhouse Gas Regulation.	HM	73	61.3	26	21.8	20	16.9	119	100
	FO	15	75	5	25	-	-	20	100

KEY: HM- Household members.FO-Forest Officers.

Source: Researcher (2021)

When the members of the households were asked if the services, they received were a source of timber, a majority at 90(75.6%) disagreed, a few 16(13.4%) agreed while 13(10.9%) were undecided as indicated in Figure 4.15. When the same was posed to the forest officers the opposite was true, with all the 20 (100%) agreeing that people used the forest as a source of timber. This agrees with the views of Costanza *et al*.,

(2017) who argues that first, provisioning services, combined with built, human and social capital, produce, for example, food, timber and fiber. Second, regulating services, combined with built, human and social capital, produce flood control, storm protection, water regulation, human disease regulation, water purification, air quality maintenance, pollination, pest control, and climate control. Third, cultural services, combined with built, human and social capital, offer recreation, aesthetic, scientific, cultural identity, sense of place, or other 'cultural' benefits. Finally, supporting services describe the basic ecosystem processes such as soil formation, primary productivity, nutrient cycling and provisioning of habitat. They contribute indirectly to human wellbeing by maintaining the processes and functions necessary for provisioning, regulating, and cultural services (Costanza *et al.*, 2017).

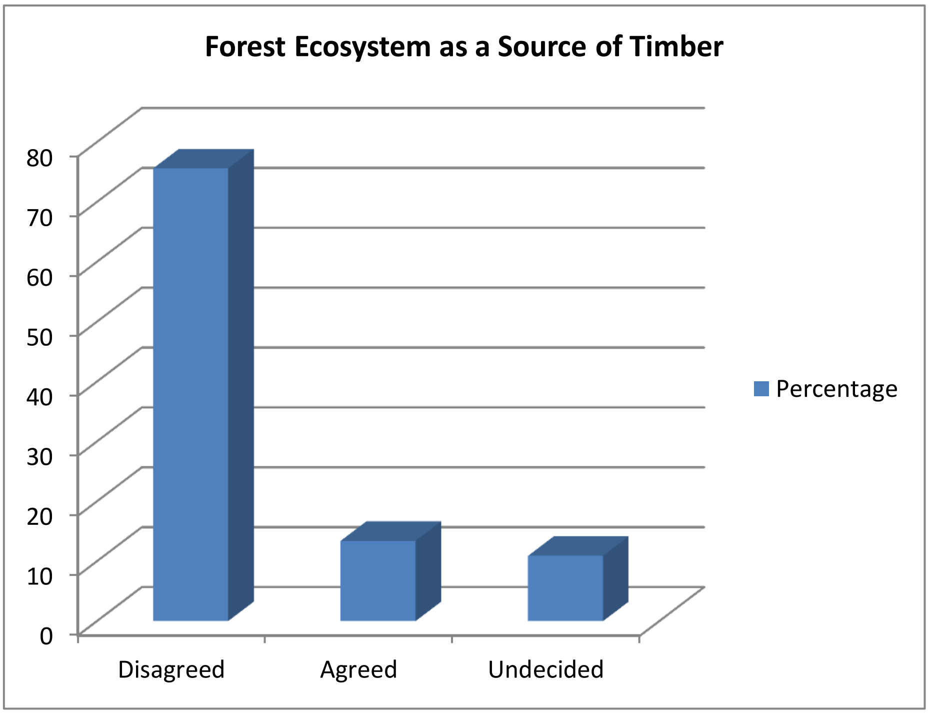

Figure 4.15: Forest Ecosystem as a Source of Timber
Source: Researcher (2021)

When the members of the households were asked if the forest ecosystem is used as a source of herbal medicine, a majority at 90(75.7%) agreed, a few at 14(11.7%)

disagreed, while 15(12.6%) were undecided. On the other hand, 16(80%) of the forest officers agreed to the same question and only 4(20%) were undecided. This agrees with the views of Costanza *et al.,* (2017) that the forest ecosystem is used as a source of herbal medicine.

Plate 4.1: Demonstration of a plant that serves as a herbal medicine.
Source: Researcher (2021)

From left is Mr. Okieka-Resource person, Bosibori-Research Assistant and Prof. Omondi. Mr. Okieka was demonstrating that the forest is a very rich source of herbal medicine. He was able to show researchers different species of plants that can cure diabetes, high blood pressure and snake bites among others.

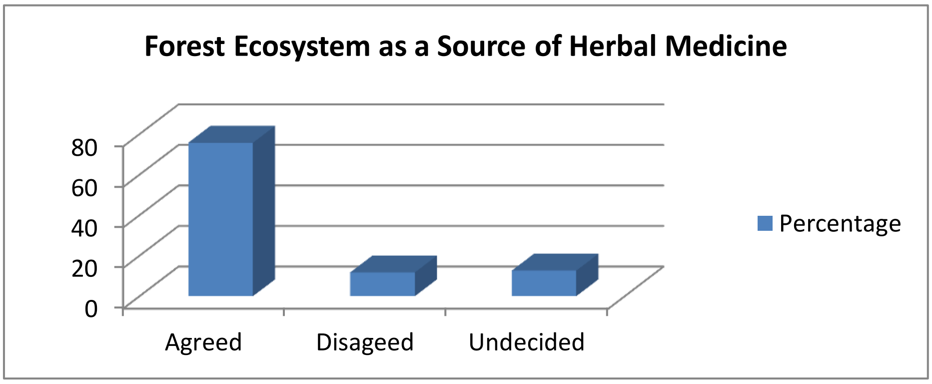

Figure 4.16: Forest Ecosystem as a Source of Herbal Medicine

Source: Researcher (2021)

When members of the households were asked if the forest ecosystem is used as a source of fodder for animals, a majority at 89 (74.8%) agreed, 20 (16.8%) disagreed while 10 (8.4%) were undecided as shown in Figure 4.17. On the other hand, a majority at 18(90%) of the forest officers agreed and only 2 (10 %) were undecided.

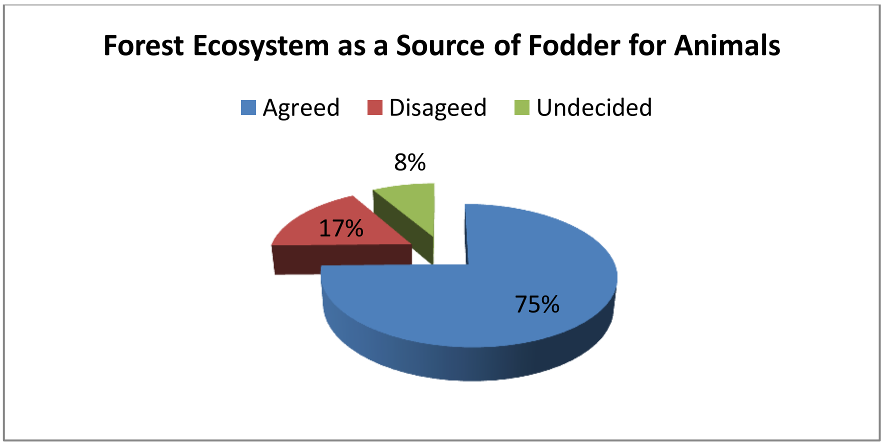

Figure 4.17: Forest Ecosystem as a Source of Fodder for Animals

Source: Researcher (2021)

On the issue of firewood, a majority at 100(84%) of the household members agreed that the forest ecosystem provided firewood, 11(9.2%) were undecided while 8 (6.8%)

disagreed as can be demonstrated in Figure 4.18. On the other hand, a majority at 17(85%) of the forest officers agreed and only 3 (15%) were undecided.

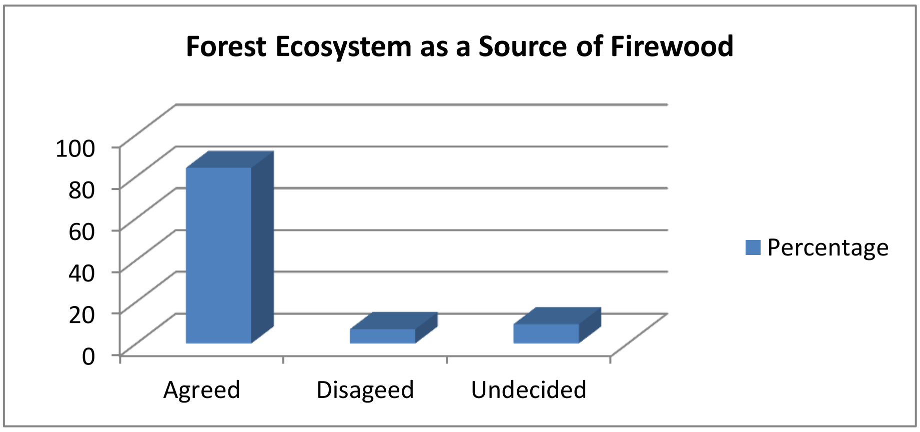

Figure 4.18: Forest Ecosystem as a Source of Firewood

Source: Researcher (2021)

On whether the forest ecosystem provided food, a majority 75(63.1%) disagreed, 26 (21.8%) agreed while 18 (15.1%) were undecided and this can be seen in Figure 4.19. On the other hand, a majority at 17(85%) of the forest officers agreed, while only 3 (15%) were undecided.

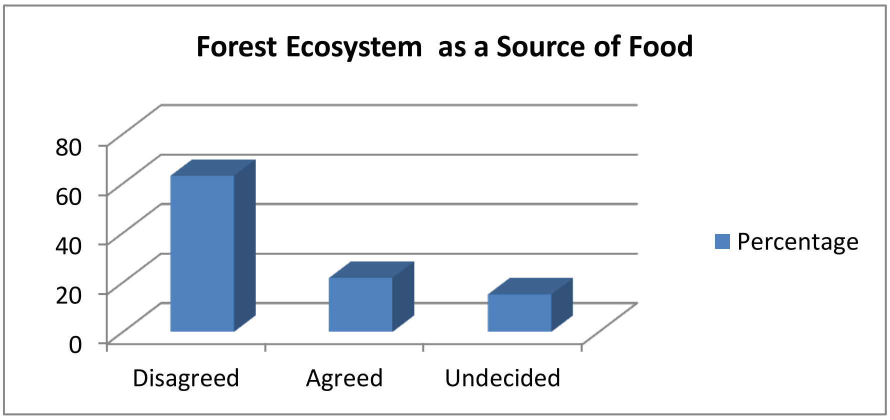

Figure 4.19: Forest Ecosystem as a Source of Food

Source: Researcher (2021)

When members of the household were asked if the forest ecosystem prevented storms, a majority at 81(68.1%) agreed, 34(28.5%) disagreed, while only 4(3.4%) were undecided as shown in Figure 4.20. On the other hand all the 20 (100%) of forest officers agreed that the forest ecosystem indeed prevented storms.

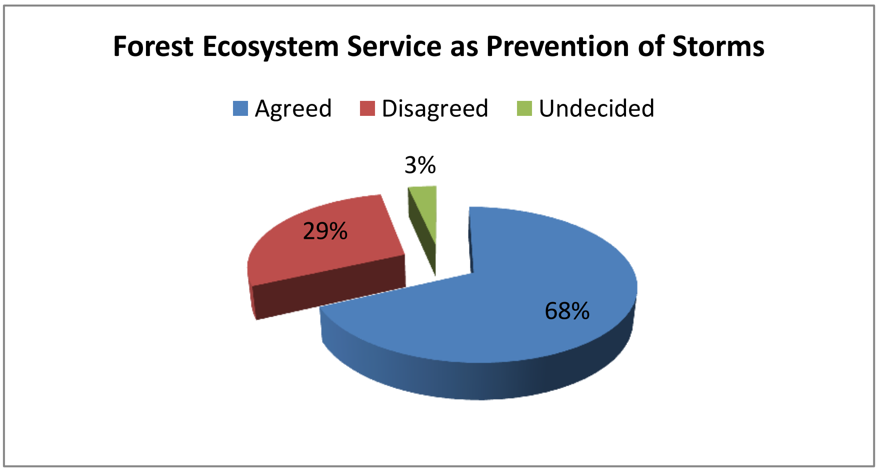

Figure 4.20: Forest Ecosystem Service as Prevention of Storms

Source: Researcher (2021)

When asked if the forest ecosystem service was to control floods, a majority at 89(74.8%) of the members of the households agreed that it indeed controlled floods, a few at 16(13.4%) disagreed while only 14(11.8%) were undecided as shown in Figure 4.21. On the same question a majority at 19 (95%) of the forest officers agreed and only 1(5%) was undecided. This shows that the forest ecosystem controls floods, which agrees with the views of Costanza *et al.*, (2017).

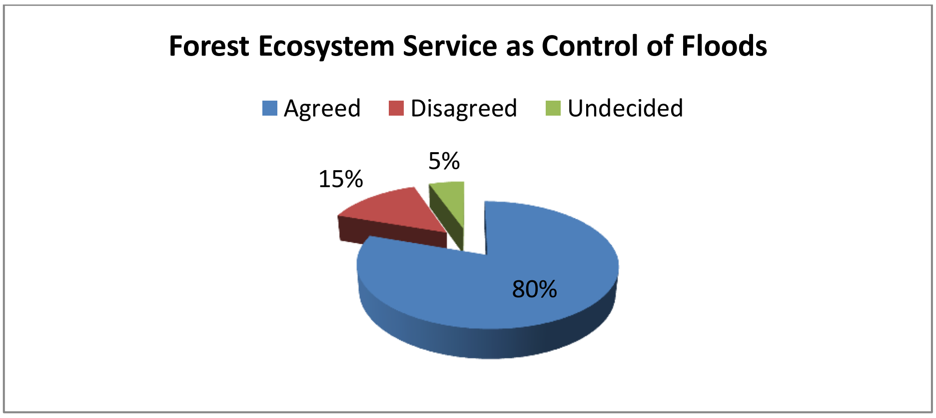

Figure 4.21: Forest Ecosystem Service as Control of Floods

Source: Researcher (2021)

When the members of the households were asked if the forest ecosystem helps in cloud formation a majority at 98(82.4%) agreed, a few at 10(8.4%) disagreed while 11(9.2%) were undecided as demonstrated in Figure 4.22. On the other hand, all the 20(100%) of the forest officers agreed on the same question. This agrees with the views of Costanza *et al*., (2017) that forests help with cloud formation and precipitation.

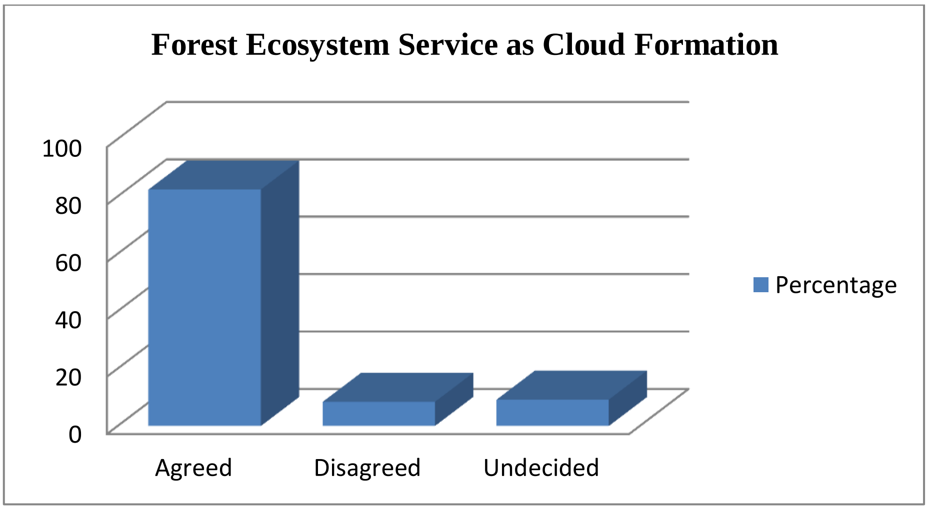

Figure 4.22: Forest Ecosystem Service as Cloud Formation
Source: Researcher (2021)

When the members of the household were further asked if the ecosystem helps in greenhouse gas regulation, a majority at 73(61.4%) agreed, 20(16.8%) disagreed, while 26(21.8%) were undecided as shown in Figure 4.23. On the other hand 15(75%) of the forest officers agreed on the same question, while only 5(25%) were undecided. This agrees with the views of Costanza *et al*., (2017) that forests indeed regulate greenhouse gases in the atmosphere.

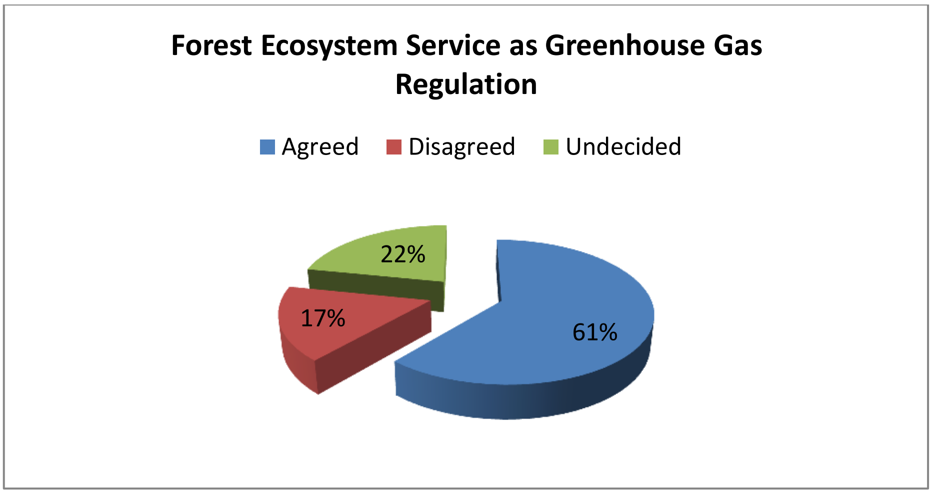

Figure 4.23: Forest Ecosystem as Greenhouse Gas Regulation

Source: Researcher (2021)

4.4 Impacts of Climate Change on Kakamega Tropical Rainforest Ecosystem

The third objective of this study was to assess the impact of climate change on Kakamega Tropical Rainforest ecosystem. In order to answer this question several responses were sought from the members of the households and the forest officers. The results are summarized in Table 4.4.

Table 4.4: ***Impacts of Climate Change on Kakamega Tropical Rainforest Ecosystem***

ITEM	Category	Agreed		Undecided		Disagreed		Total	
		F	%	F	%	F	%	F	%
Changes in productivity	HM	97	81.5	6	5.0	16	13.5	119	100
	FO	20	100	-	-	-	-	20	100
Functional Trait Composition	HM	90	75.6	10	8.4	19	16	119	100
	FO	20	100	-	-	-	-	20	100
Species extinction or range redistribution	HM	106	89.1	3	2.5	10	8.4	119	100
	FO	20	100	-	-	-	-	20	100
Increased fire frequency	HM	34	28.6	24	20.2	61	51.2	119	100
	FO	19	95	1	5	-	-	20	100
Changes in precipitation and warming	HM	92	77.3	-	-	27	22.7	119	100
	FO	20	100	-	-	-	-	20	100

KEY: HM-Household members.FO-Forest Officers

Source: Researcher (2021)

The researcher sought to know if one of the impacts was changes in productivity. On this question a majority at 97(81.5%) of the members of the households agreed that, indeed it caused a change in productivity, a few 16(13.5%) disagreed while only 6(5%) were undecided as indicated in Figure 4.24. On the other hand all the 20(100%) of the forest officers agreed that one of the impacts of the forest ecosystem was the changes in productivity.

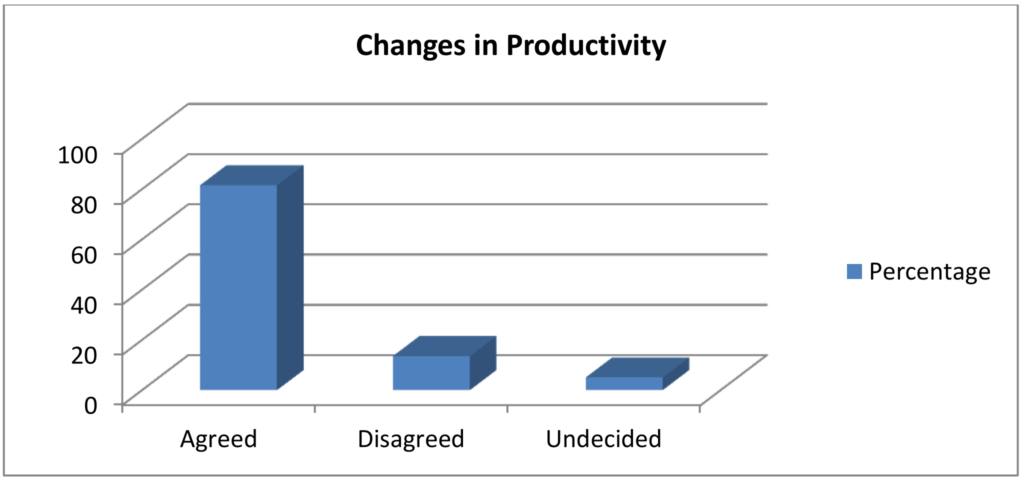

Figure 4.24: Changes in Productivity

Source: Researcher (2021)

When the members of the households were asked if one of the impacts on the forest ecosystem was functional traits composition, a majority at 90(75.7%) agreed, a few at 19(15.9%) disagreed, while only 10(8.4%) were undecided as demonstrated in Figure 4.25. On the other hand all the 20(100%) of the forest officers agreed.

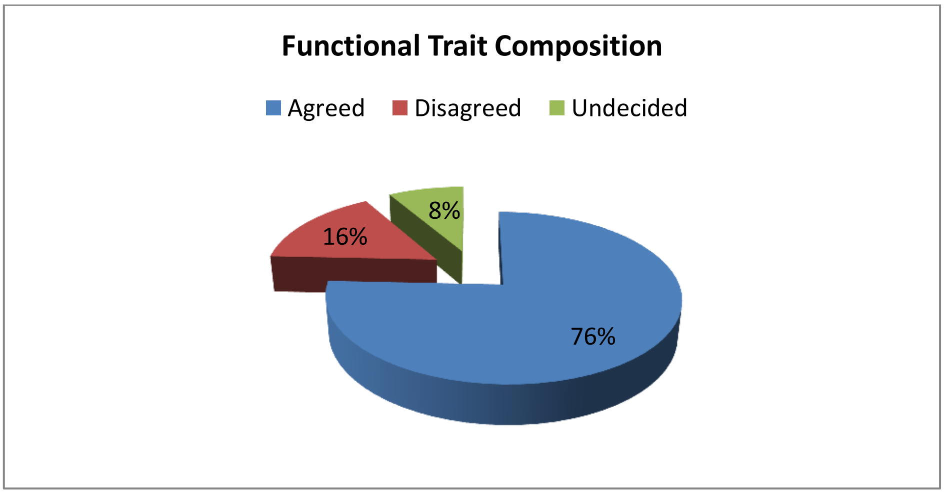

Figure 4.25: Functional Trait Composition

Source: Researcher (2021)

When asked if the forest ecosystem impact was that it led to species extinction or range redistribution, a majority at 106(89.1%) agreed, a few at 10(8.4%) disagreed while only 3(2.5%) were undecided (see Figure 4.26). On the same question, all the 20(100%) forest officers agreed. This shows that extinction of species or range redistribution of species was one of the impacts of forest ecosystem destruction as agreed by Malhi *et al.*, (2009) and IPCC (2013) that the effects of climate change may have direct impacts on vegetation such as changes in productivity, functional trait composition, species extinction or range redistribution. These changes may be associated with increased drought stress, drying or dieback. Climate change can also have indirect impacts on vegetation such as increased fire frequency. Global and regional climate simulations for the next few decades project changes in precipitation and warming that may severely impact major biomes all over the world.

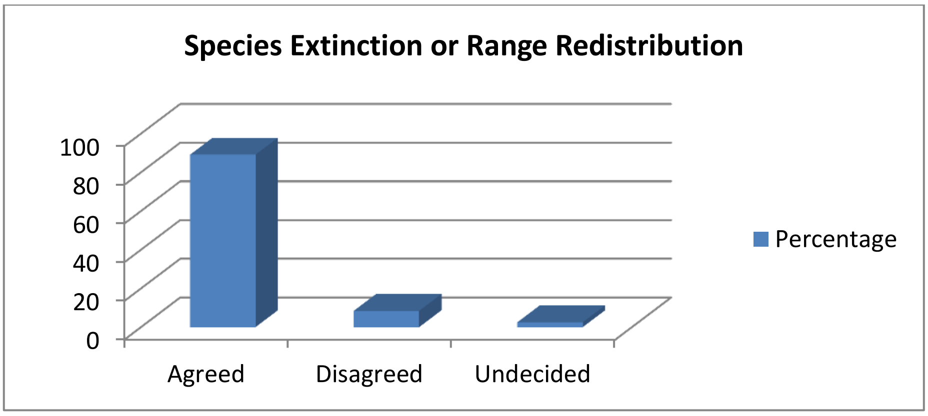

Figure 4.26: Species Extinction or Range Redistribution
Source: Researcher (2021)

When the members of the households were asked if one of the impacts was increased fire frequency, a majority at 61(51.2%) disagreed, 34(28.6%) agreed, while 24(20.2%) were undecided as shown in Figure 4.26. On the other hand, a majority at 19(95%) of the forest officers agreed, while only 1(5%) was undecided. This shows that there was disagreement between the forest officers' views and the members of the households' views but nonetheless, increased fire frequency was an impact of climate change as observed by Malhi *et al.*, (2009) and IPCC (2013).

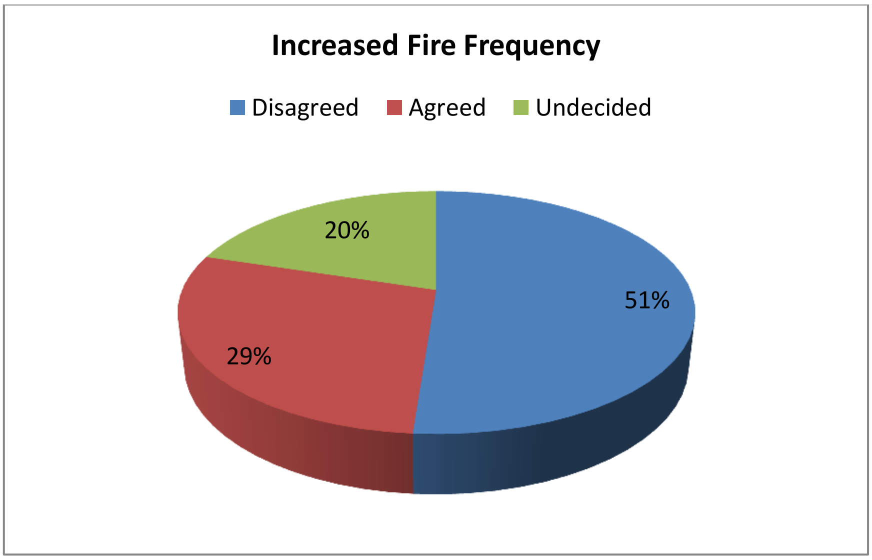

Figure 4.27: Increased Fire Frequency

Source: Researcher (2021)

When the members of the households were asked if one of the impacts of the forest ecosystem was changes in precipitation and warming. The majority at 92(77.3%) agreed, 27 (22.7%) disagreed and none was undecided as demonstrated in Figure 4.28. On the other hand all the 20(100%) of the forest officers agreed. This agrees with the views of Chen and Chu, (2014) that changes in precipitation and warming was one of the impacts of climate change in the Kakamega Tropical Rainforest ecosystem.

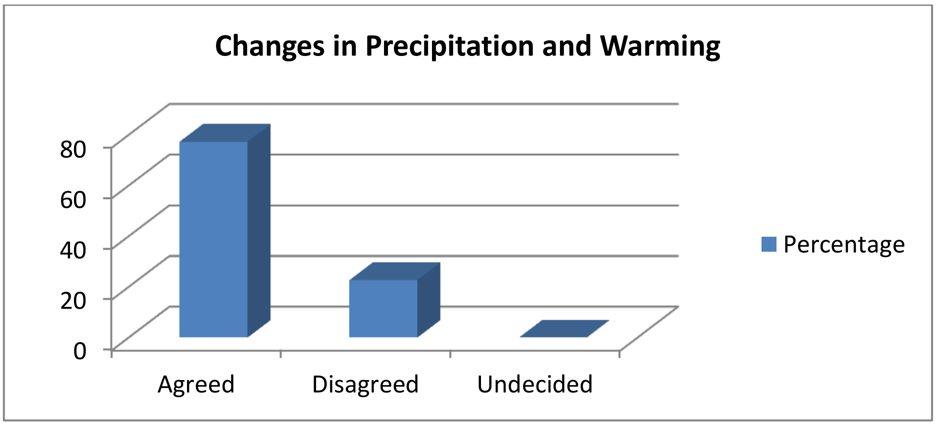

Figure 4.28 Changes in Precipitation and Warming

Source: Researcher (2021)

4.5 Ecosystem-Based Adaptation to Climate Change in Kakamega Tropical Rainforest

The fourth objective of this study was to evaluate Ecosystem-based Adaptation to climate change in Kakamega Tropical Rainforest. In order to address this objective, the researcher sought answers to several questions. The results are presented in Table 4.5.

Table 4.5: ***Ecosystem-based Adaptation to Climate Change in Kakamega Tropical Rainforest***

ITEM	Category	Agreed		Undecided		Disagreed		Total	
		F	%	F	%	F	%	F	%
EbA are measures which use ecosystem services to attain or support adaptation to climate change	HM	25	21.0	7	5.9	87	73.1	119	100
	FO	20	100	-	-	-	-	20	100
EbA activities are policy and behavioral changes	HM	97	81.5	6	5.0	16	13.5	119	100
	FO	20	100	-	-	-	-	20	100
EbA activities are targeted management	HM	89	74.8	16	13.4	14	11.8	119	100
	FO	18	90	2	10	-	-	20	100
EbA activities are conservation activities	HM	87	73.1	10	8.4	22	18.5	119	100
	FO	18	90	2	10	-	-	20	100
EbA are restoration of highly degraded dry forest	HM	87	73.1	10	8.4	22	18.5	119	100
	FO	18	90	2	10	-	-	20	100
EbA activities is reducing biodiversity loss	HM	87	73.1	15	12.6	17	14.3	119	100
	FO	20	100	-	-	-	-	20	100
Do you think forest ecosystems help to adopt or mitigate climate	HM	84	70.6	14	11.8	21	17.7	119	100
	FO	17	85	3	15	-	-	20	100

KEY: HM-Household members.FO-Forest Officers
Source: Researcher (2021)
The respondents were first asked if they agree or disagree with the statement that measures which use ecosystem services to attain or support adaptation to climate change is what is indeed the definition of Ecosystem-based Adaptation. On this question, a majority at 87(73.2%) disagreed, 25(21%) agreed while only 7(5.9%) were undecided as can be seen in Figure 4.29. On the same question, all the 20(100%) forest officers agreed with that definition.

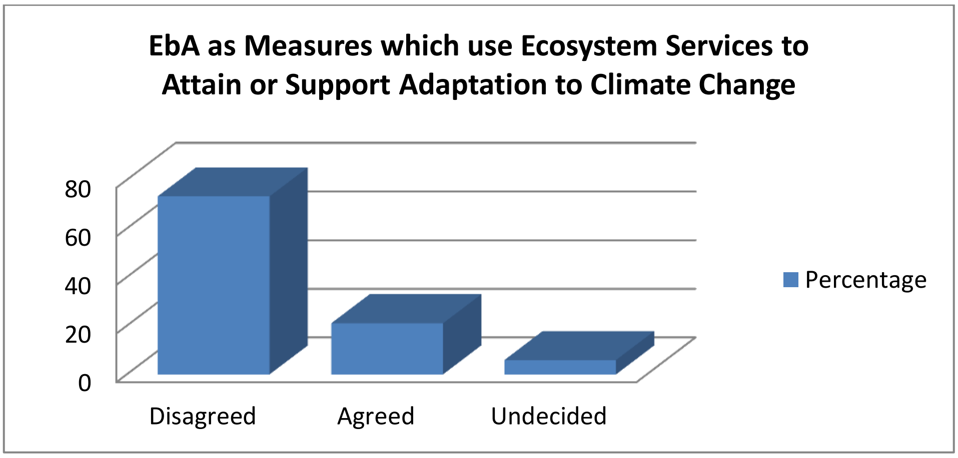

Figure 4.29: EbA as Measures which use Ecosystem Services to Attain orSupport Adaptation to Climate Change
Source: Researcher (2021)

When the members of the households were asked whether Ecosystem-based Adaptation were policy and behavioural changes, a majority at 97(81.5%) agreed, 16(13.4%) disagreed, while only 6(5%) were undecided as show on Figure 4.30. On the other hand, all the 20(100%) of the forest officers agreed that indeed Ecosystem-based Adaptation were policy and behavioural changes. This is in line with the views of Pramova *et al.*, (2012).

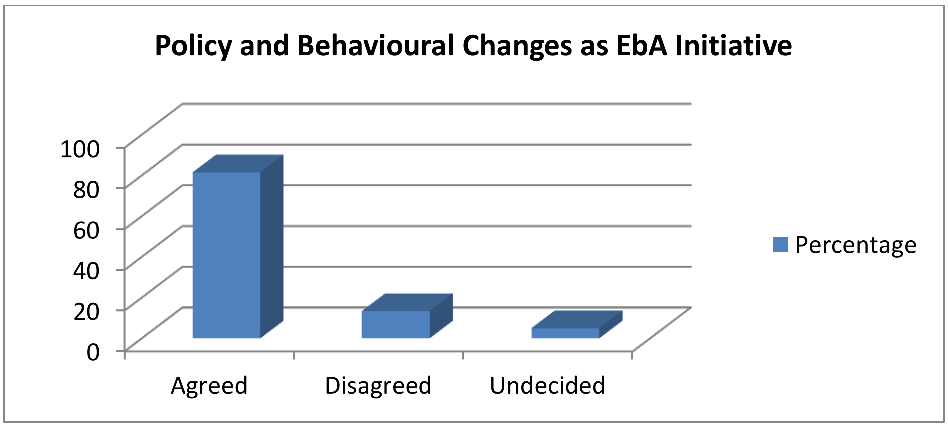

Figure 4.30: Policy and Behavioural Changes as EbA Initiative

Source: Researcher (2021)

When the members of the households were asked if the targeted management was among the EbA initiatives implemented in Kakamega Tropical Rainforest, a majority of the members of the household at 89(74.8%) agreed, 14(11.8%) disagreed and another 16(13.4%) were undecided as demonstrated in Figure 4.31. On the other hand, a majority of the forest officers at 18(90%) agreed and 2(10%) were undecided.

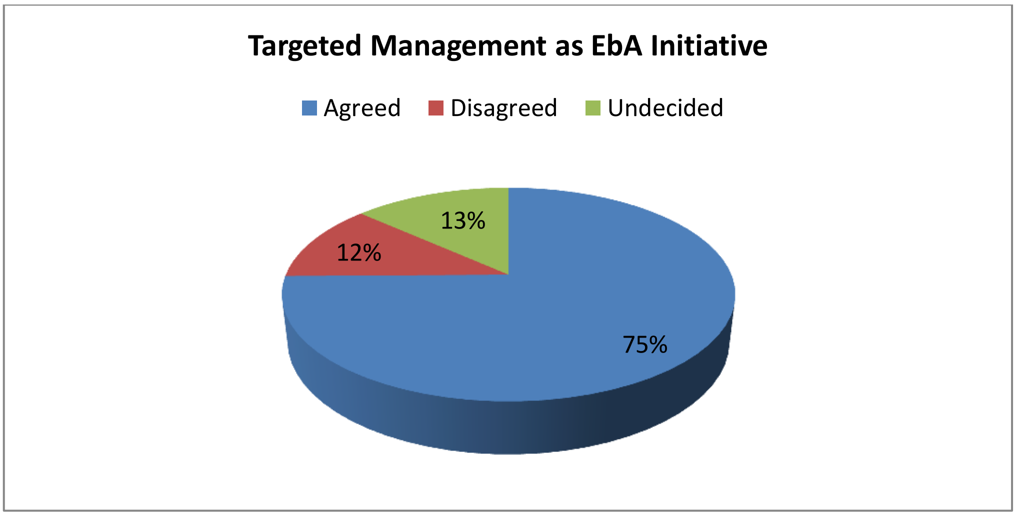

Figure 4.31: Targeted Management as EbA Initiative

Source: Researcher (2021)

On the issue of whether conservation activities were one of the EbA activities implemented in Kakamega Tropical Rainforest, a majority of the members of the households at 87(73.1%) agreed, 22(18.5%) disagreed while 10(8.4%) were undecided as shown in Figure 4.32. On the other hand, the majority of the forest officers at 18(90%) agreed, while 2(10%) were undecided. Pramova *et al.*, (2012) and Thorlakson, & Henry, (2012) argue that EbA approaches include sustainable management, conservation and restoration of ecosystems for the purpose of providing services to help people adapt to climate change impacts. Specifically, for terrestrial forest communities, EbA may include interventions of conserving or restoring forest on the land slope to reduce landslides or losses of water or developing diversified agroforestry to deal with climate variabilities; and conservation of agro biodiversity to provide specific gene pools for crops or livestock to adapt to climate change.

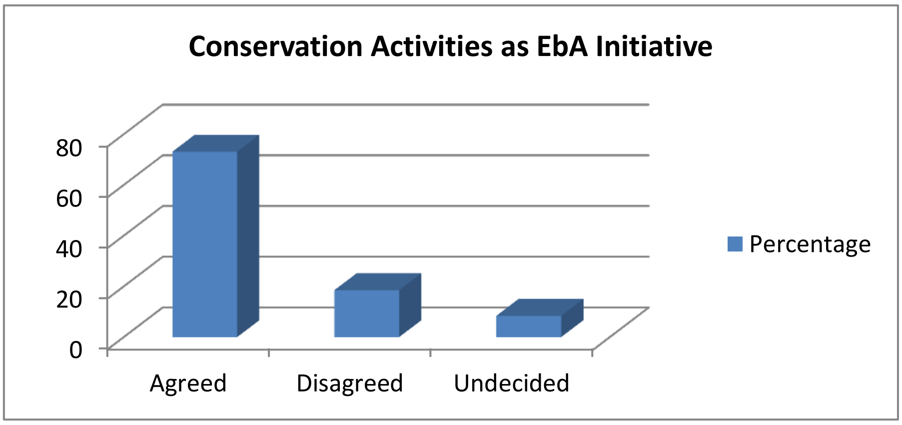

Figure 4.32: Conservation Activities as EbA Initiative
Source: Researcher (2021)

The members of the households were also asked if the restoration of the highly degraded dry forest was one of the EbA initiatives implemented in the forest, and a majority at 87 (73.1%) agreed, 22(18.5%) disagreed, while 10(8.4%) were undecided as demonstrated in Figure 4.33. On the other hand, a majority at 18(90%) of forest officers agreed and only 2(10%) were undecided. None disagreed.

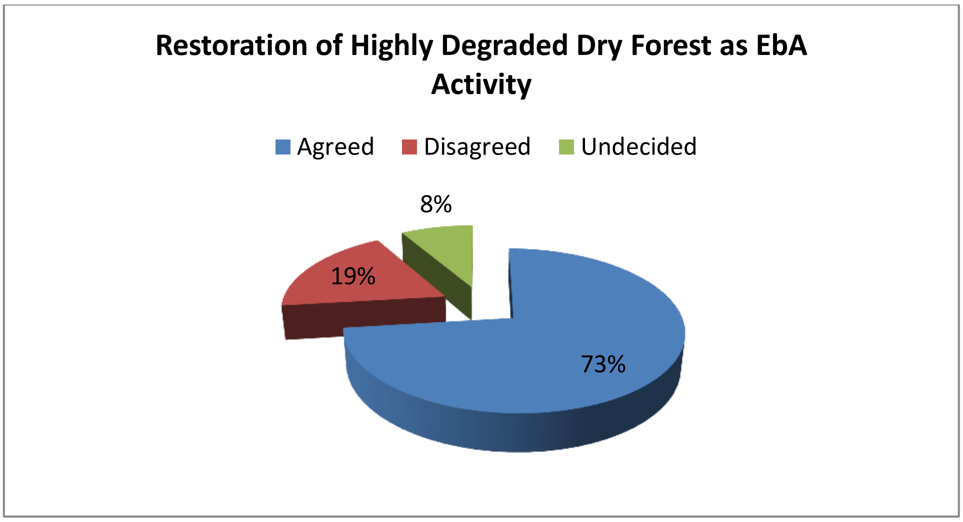

Figure 4.33: Restoration of Highly Degraded Dry Forest as EbA Activity

Source: Researcher (2021)

Asked if reduction on the biodiversity loss was one of the EbA initiatives implemented in the Kakamega tropical rainforest ecosystem, a majority at 87(73.1%) of the members of the households agreed, 17(14.3%) disagreed and 15(12.6%) were undecided as can be seen in Figure 4.34. On the other hand, all the 20(100%) forest officers agreed. This shows that reduction of biodiversity loss was one of the EbA initiatives in the area as noted by Pramova *et al*. (2012) and Thorlakson, T. & Henry, N. (2012).

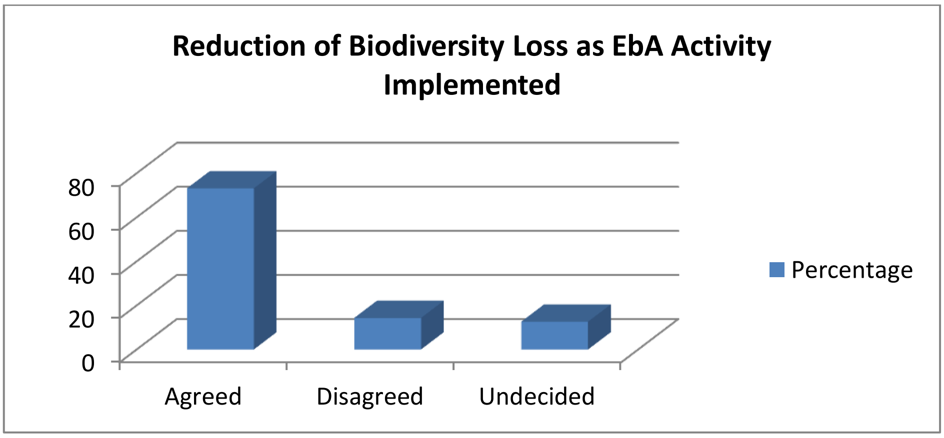

Figure 4.34: Reduction of Biodiversity Loss as EbA Activity Implemented

Source: Researcher (2021)

When members of the households were asked their opinion if the forest ecosystem helped to adapt or mitigate climate change, a majority at 84(70.6%) agreed, 21(17.7%) disagreed, while 14(11.8%) were undecided as indicated in Figure 4.35. On the other hand, 17(85%) of the forest officers agreed and only 3(15%) were undecided. This agrees with the views of Pramova *et al*. (2012) and Thorlakson, T. & Henry, N. (2012) that forests help to mitigate climate change.

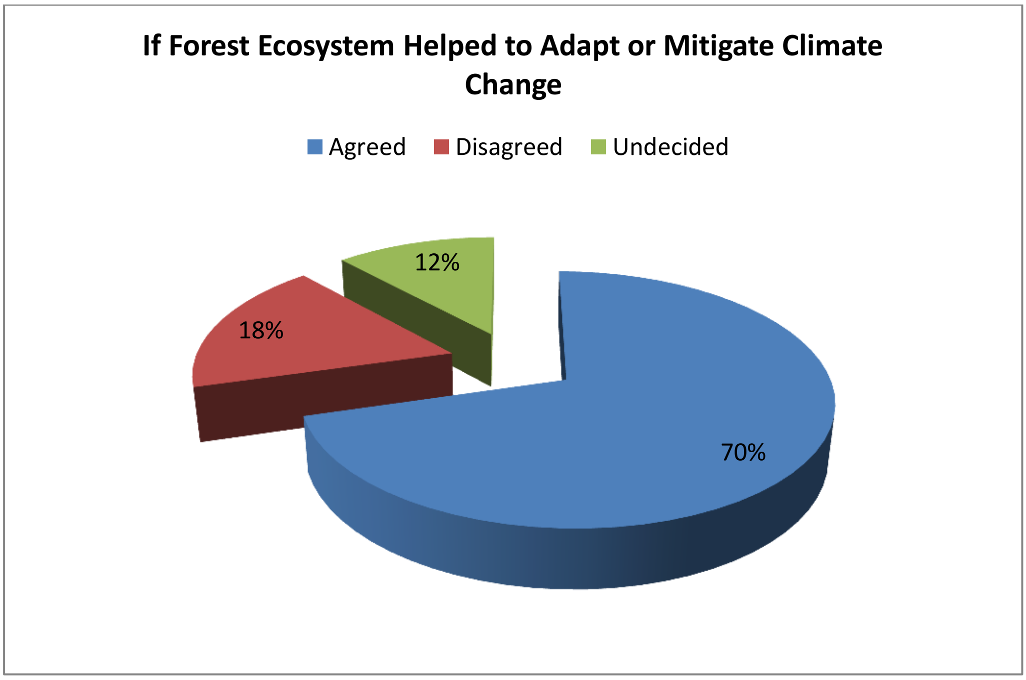

Figure 4.35: If Forest Ecosystem Helped to Adapt or Mitigate Climate Change
Source: Researcher (2021)

4.6 Challenges and Constraints Facing Implementation of EbA Initiatives in Kakamega Tropical Rainforest

The fifth and last objective was to establish challenges and constraints facing implementation of EbA initiatives in Kakamega Tropical rainforest. In a bid to answer questions related to this objective, the study respondents were asked to respond to a variety of issues. Table 4.6gives a summary of the issues raised.

Table 4.6: ***Challenges and Constraints Facing Implementation of EbA Initiatives in Kakamega Tropical Rainforest***

ITEM	Category	Agreed		Undecided		Disagreed		Total	
		F	**%**	**F**	**%**	**F**	**%**	**F**	**%**
Continued uncertainties around future climatic conditions	HM	42	35.3	9	7.6	68.0	57.1	119	100
	FO	16	80	4	20	-	-	20	100
Higher population growth rate	HM	86	72.3	5	4.2	28	23.5	119	100
	FO	18	90	2	10	-	-	20	100
Deforestation	HM	95	79.8	1	0.8	23	19.4	119	100
	FO	20	100	-	-	-	-	20	100
Poverty	HM	27	22.7	11	9.2	81	68.1	119	100
	FO	16	80	4	20	-	-	20	100
Economic reasons like fluctuation of markets	HM	21	17.6	14	11.8	84	70.6	119	100
	FO	17	85	3	15	-	-	20	100
Physical reasons like remoteness	HM	24	20.2	19	16.0	76	63.8	119	100
	FO	18	90	2	10	-	-	20	100
Social-political reasons	HM	28	23.5	10	8.4	81	68.1	119	100
	FO	19	95	1	5	-	-	20	100

KEY: HM-Household Members.FO-Forest Officers

Source: Researcher (2021)

In reference to continued uncertainties around future climate change a majority at 68(57.1%) of the households disagreed, 42(35.3%) agreed while 9(7.6%) were undecided as shown in Figure 4.36. On the other hand, the majority at 16(80%) of the forest officers agreed and only 4(20%) disagreed. This shows that there were differences in opinion between the two sets of respondents. Jones et al., (2012) argues that when the impact of climate change on ecosystems is considered in tandem with resulting impact to ecosystem services, significant uncertainty around the delivery of ecosystem services under various climate change conditions remains (Jones *et al.*, 2012).

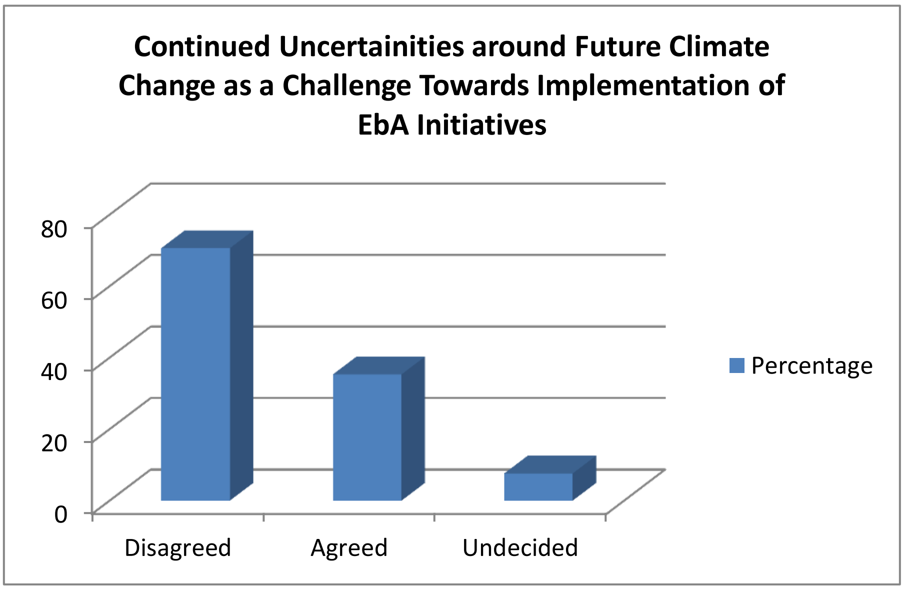

Figure 4.36: Continued Uncertainities around Future Climate Change as a Challenge towards Implementation of EbA Initiatives

Source: Researcher (2021)

In reference to higher population growth rate as one of the constraints or challenges facing the implementation of EbA initiatives, a majority at 86(72.3%) of households agreed, 28(23.5%) disagreed, while 5(4.2%) were undecided as can be seen in Figure 4.37. On the other hand, a majority at 18(90%) of the forest officers agreed and only 2(10%) were undecided.

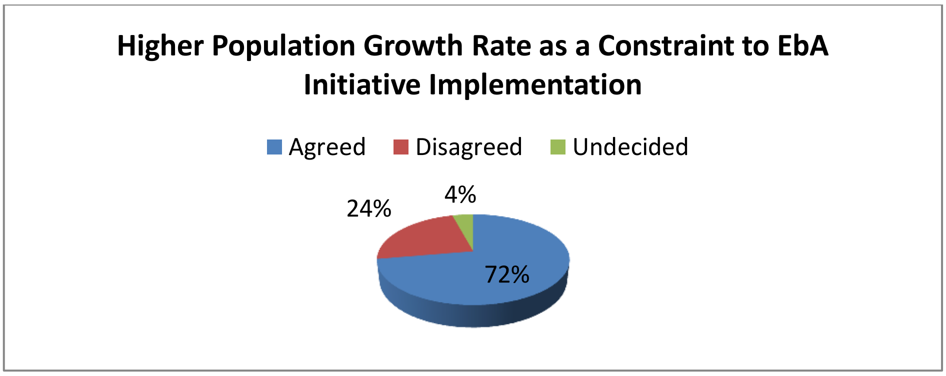

Figure 4.37: Higher Population Growth Rate as a Constraint to EbA Initiative Implementation

Source: Researcher (2021)

In relation to deforestation as one of the challenges facing the implementation of EbA initiatives in Kakamega Tropical Rainforest ecosystem, a majority at 95(79.8%) of the members of the households agreed that it was indeed a challenge, 23(19.3%) disagreed, while only 1(0.8%) was undecided as shown in Figure 4.38. On the other hand, all the 20(100%) of the forest officers agreed that deforestation was one of the challenges facing the implementation of EbA initiatives in Kakamega Tropical Rainforest.

Indeed, according to Butler (2009) 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, the inequitable distribution of wealth and power, population growth, overpopulation and urbanization.

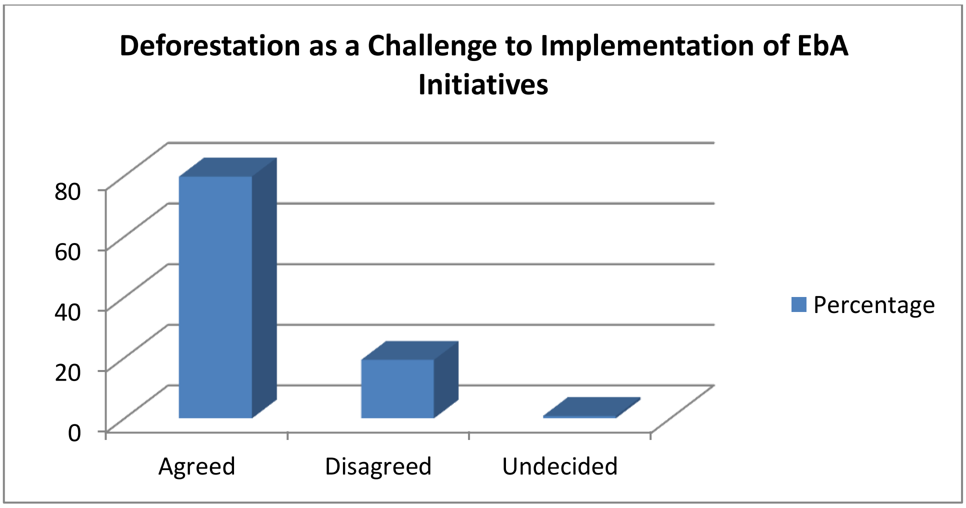

Figure 4.38: Deforestation as a Challenge to Implementation of EbA Initiatives
Source: Researcher (2021)

When the members of the households were asked if poverty was one of the challenges facing the implementation of EbA in Kakamega Tropical rainforest ecosystem, a majority at 81(68.1%) of households disagreed, while 27(22.7%) agreed, and a few at11(9.2%) were undecided as demonstrated in Figure 4.39. A majority at 16 (80%) of the forest officers agreed that poverty was one of the challenges facing the implementation of EbA initiatives in Kakamega Tropical Rainforest while only 4(20%) were undecided, and non-disagreed with the statement. This agrees with the views of Maraseni (2012) who argues that:

> "To the poor who depend on forest ecosystems, forests link with poverty in a complex way. On the one hand, forests provide them with food, timber products and non-timber products, ecosystem services, and employment opportunities that could help them reduce their poverty. On the other hand, living in rural forest areas means heavily depending on natural-resources that are increasingly unstable due to environmental changes like land degradation and climate change" (Maraseni, 2012).

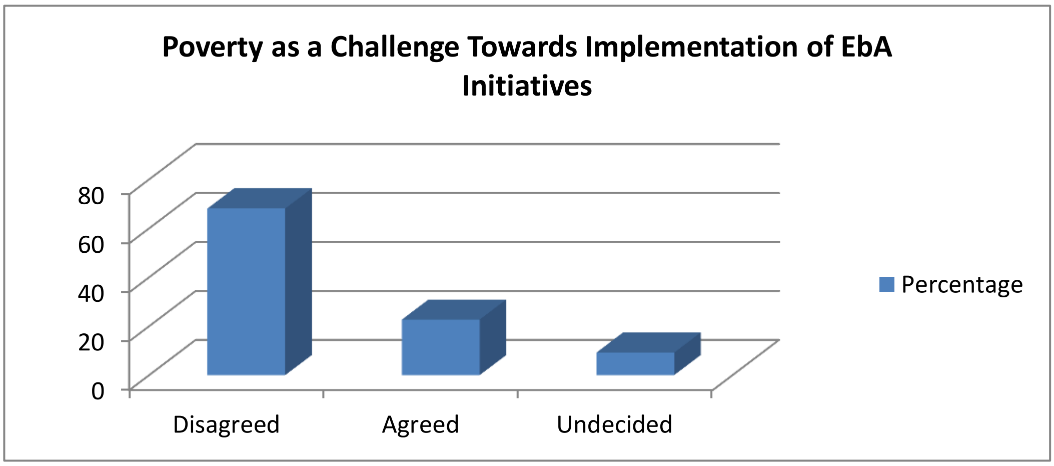

Figure 4.39: Poverty as a Challenge towards Implementation of EbA Initiatives
Source: Researcher (2021)

When the members of the households were asked if economic reasons like fluctuation of the markets was another challenge, a majority at 84(70.6%) disagreed, a few 21(17.6%) agreed while 14(11.8%) were undecided as demonstrated in Figure 4.40. On the other hand, a majority at 17(85%) of the forest officers agreed with this statement while only 3(15%) were undecided.

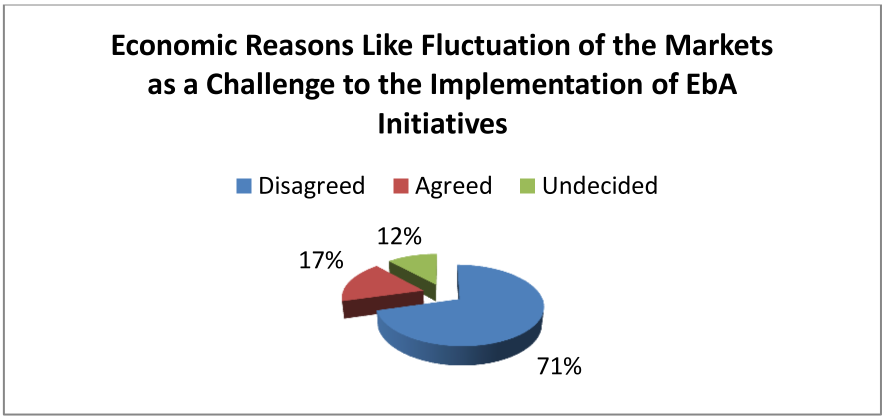

Figure 4.40: Economic Reasons like Fluctuation of the Markets as a Challenge to the Implementation of EbA Initiatives

Source: Researcher (2021)

When members of the household were asked if physical reasons like remoteness was a challenge to the implementation of EbA initiatives in the forest ecosystem, a majority at 76(63.8%) of households disagreed, 24(20.2%) agreed, while 19(16.0%) were undecided as indicated in Figure 4.41. On the other hand, 18(90%) of the forest officers agreed while only 2(10%) were undecided. This shows that there was a disagreement between the two groups of respondents with the members of the households disagreeing while the forest officers agreed.

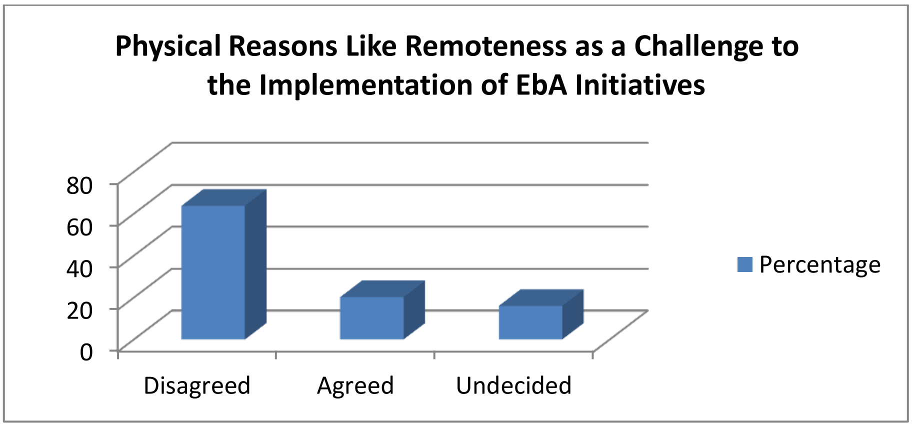

Figure 4.41: Physical Reasons like Remoteness as a Challenge to the Implementation of EbA Initiatives

Source: Researcher (2021)

When asked if the challenges that faced implementation of EbA initiatives were related to social political reasons, a majority at 81(68.1%) agreed, 28(23.5%) disagreed, while 10(8.4%) were undecided among the members of the households as can be seen in Figure 4.42. On the other hand, a majority at 19(95%) of the forest officers agreed that social political reasons were some of the challenges facing the implementation of EbA in Kakamega Tropical rainforest ecosystem. None disagreed and only 1(5%) was undecided. This shows that social political reasons were among the challenges facing the forest ecosystem.

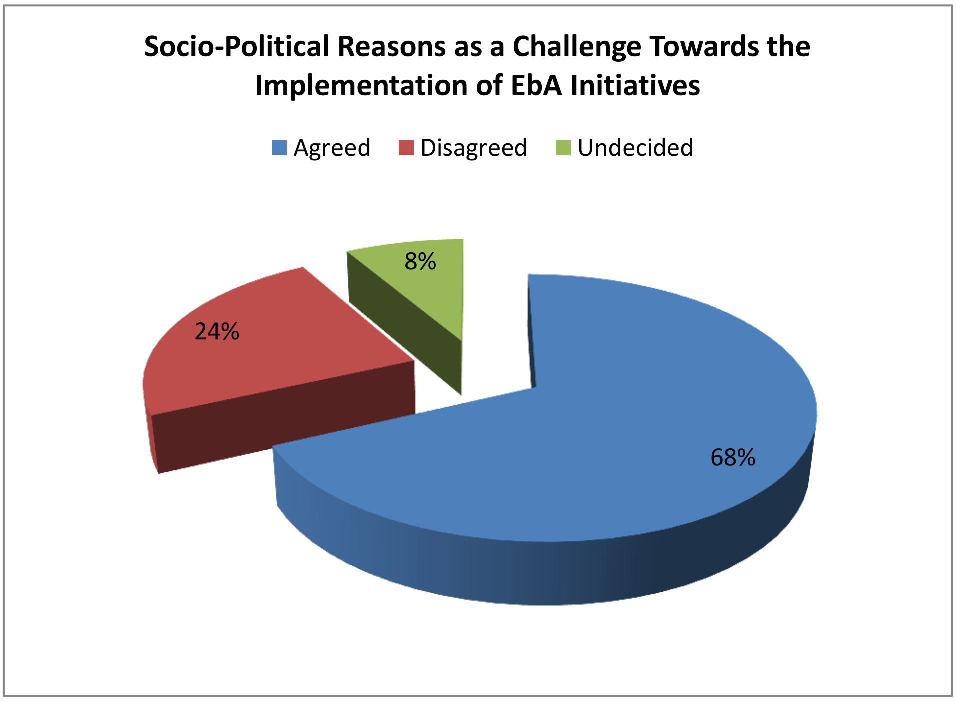

Figure 4.42: Socio-Political Reasons as a Challenge towards the Implementation of EbA Initiatives

Source: Researcher (2021)

The respondents were asked to suggest ways in which the National/County governments can have lasting solutions to the effects of climate change on Kakamega Tropical Rainforest ecosystem. Among the members of the household, a majority at 43(36.1%) said that the management should allow the residents to benefit, followed by those who said that the government should control the movement of animals

39(32.8%), then followed by those who said that the government should formulate relevant policies to check the ecosystem 24(20.2%), and the lastly 13(10.9%) suggested that the forest should be guarded using an electric fence as demonstrated in Figure 4.43.

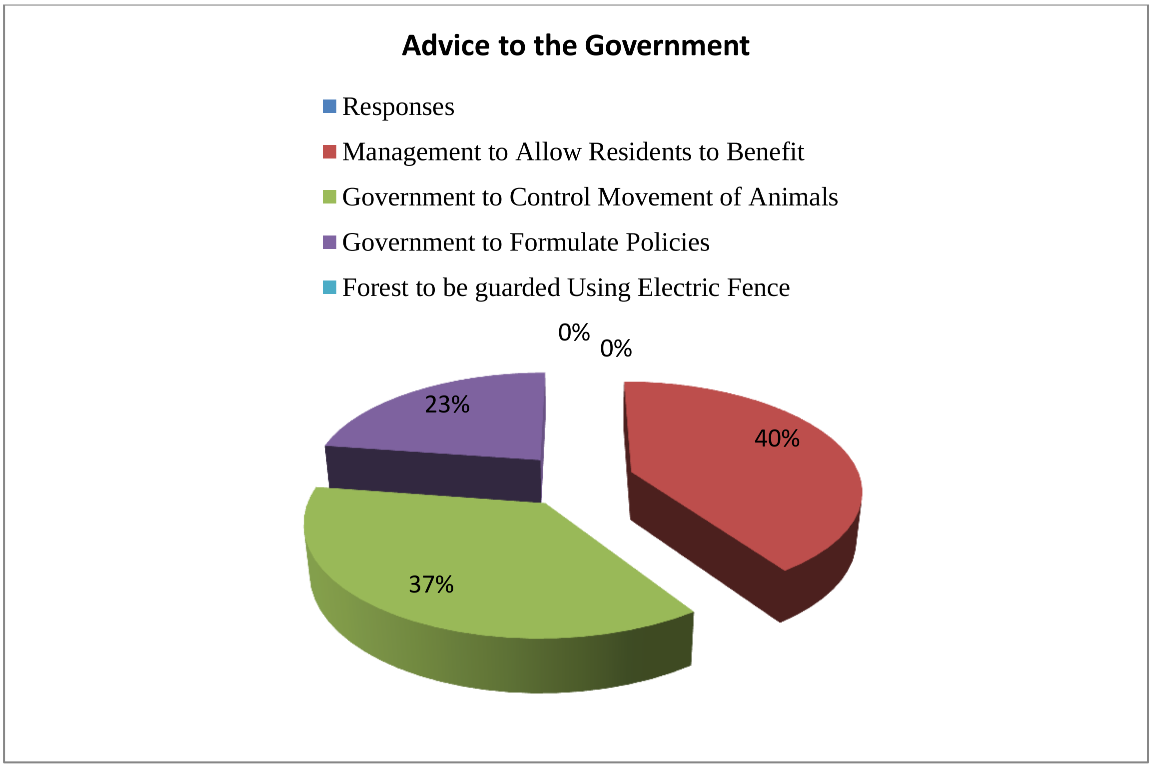

Figure 4.43: Advice to the Government
Source: Researcher (2021)

On the other hand, when the forest officers were asked to give similar suggestions, a majority of them 12(60%) said that the residents should benefit, then followed by 7(35%) who argued that the government should control the movement of animals and only 1(5%) suggested that the forest be guarded by use of the electric fence. This shows therefore that both categories of respondents are of the idea that residents living around the forest ecosystem should be asked to help in conservation matters and at the same time benefit from the forest ecosystem.

CHAPTER FIVE

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

5.0 Introduction

This section contains the summary of the findings, conclusions, recommendations and suggestions for further research. The study sought to assess the Impact of Climate Change and application of EbA in Kakamega Tropical Rainforest. The following is a summary of the findings of the study.

5.1 Summary of Study Findings

The study came up with the following findings based on the objectives of the study:

5.1.1 Spatial and Temporal Characteristics of Climate Change

The members of the households were asked what they perceived to be climate change. The majority viewed climate change as very extreme temperatures, very extreme precipitation and also both as very extreme temperatures and precipitation, and this shows that a majority of the members of the households' respondents viewed climate change as both extreme changes in both temperatures and precipitation.

The views on the same question posed to forest officers was not different, all the forest officers agreed that climate change was having both very extreme temperatures and precipitation. This shows that both the members of the households and the forest officers were of the view that climate change was the cause of extreme temperatures and precipitation.

A majority of both the members of the households and forest officers had witnessed climate change in the area. This shows that climate change is a normal observable occurrence that can be witnessed by people living near the forest.

When the members of the households and forest officers were both asked to indicate the spatial and temporal characteristics of climate change in Kakamega Tropical Rainforest, the majority viewed that as a shift in the rainy and dry seasons.

A majority of both the members of the households and forest officers felt that one of the spatial and temporal characteristics of climate change was drought. This shows that the majority of the households' respondents and forest officers' respondents view drought as one of the consequences of climate change. A majority of the members of the households and forest officers also felt that one of the spatial and temporal characteristics of climate change was intense rainfall. This shows that majority of the members of the households and forest officers agreed that intense rainfall was part of the effect of climate change.

A majority of both the members of the households and forest officers agreed that one of the spatial and temporal characteristics of climate change was less rainfall.

5.1.2 Ecosystem Services of Kakamega Tropical Rainforest.

Majority of the members of the households disagreed that the services they received from the forest ecosystem were a source of timber. However, when the same question was posed to the forest officers, the opposite was true, with all the twenty forest officers being in agreement with the fact that people used the forest as a source of timber.

As a source of firewood, majority of the household members agreed that the forest ecosystem indeed assisted them as a source of firewood. This was also in agreement with forest officers who all agreed that the forest ecosystem was indeed used as a source of firewood.

When the members of the households were asked if the forest ecosystem was used as a source of herbal medicine, a majority of them were in agreement. This was also true for the forest officers who also agreed with the same question.

When members of the households were asked if the forest ecosystem is used as a source of fodder for livestock, a majority of them were in agreement. A majority of the forest officers also agreed that indeed the forest ecosystem was used as a source of fodder for livestock.

Again, when the members of the households and forest officers were asked if the forest ecosystem was used as a source of food, both categories of respondents agreed that the forest ecosystem was indeed used as a source of food.

When both the members of the households and forest officers were asked if the forest ecosystem prevents storms, a majority of the household members agreed while all the twenty forest officers interviewed agreed that the forest ecosystem indeed prevents storms.

When asked if the forest ecosystem controls floods, a majority of both the members of the households and forest officers agreed that it indeed controlled floods.

When the members of the households and forest officers were asked if the ecosystem service helps in cloud formation, a majority of both categories of the respondents agreed on the same question. Therefore forests help with cloud formation and precipitation.

When the members of the households were further asked if the ecosystem helps in greenhouse gas regulation, a majority of both the household members and forest officers agreed. Thus forests indeed regulate greenhouse gases in the atmosphere.

5.1.3 Impacts of Climate Change on Kakamega Tropical Rainforest Ecosystem

The researcher sought to know if one of the impacts was changes in productivity, and on this question a majority of the members of the households were in agreement, while all the forest officers agreed that one of the impacts of the forest ecosystem was the changes in productivity.

When the members of the households were asked if one of the impacts of climate change on the forest ecosystem was functional traits composition, a majority of the members of the households agreed, while all the twenty forest officers interviewed also agreed.

A majority of the members of the households and forest officers agreed that one of the impacts of the forest ecosystem was that it led to species extinction or range redistribution. This shows that extinction of species or range distribution of species was one of the impacts of forest ecosystem destruction.

When the members of the households were asked if one of the impacts was increased fire frequency, a majority of them disagreed while a majority of forest officers agreed. This shows that there was disagreement between the forest officers' views and those of the members of the households.

When the members of the households and forest officers were asked if one of the impacts of the forest ecosystem was changes in precipitation and warming, both the members of the households and forest officers were in agreement. Thus changes in precipitation and warming was one of the impacts of climate change in the Kakamega forest ecosystem.

5.1.4 Ecosystem-Based Adaptation to Climate Change in Kakamega Tropical Rainforest

The respondents were first asked if they agree or disagree with the statement that measures which use ecosystem services to attain or support adaptation to climate change is what is indeed the definition of Ecosystem-based Adaptation. On this question, a majority of the household members disagreed while on the other hand a majority of the forest officers agreed with the statement.

When the members of the households were asked which Ecosystem-based Adaptation initiative, have been implemented in Kakamega Tropical rainforest, and if policy and behavioral changes were among the initiatives implemented, a majority of the members of the households agreed, while all of the forest officers agreed on the same.

Both the household members and forest officers agreed that the targeted management was among the EbA initiatives implemented in Kakamega Tropical Rainforest.

The members of the households were also asked if the restoration of the highly degraded dry forest was one of the EbA initiatives implemented in the forest, and a majority of both the members of the households and forest officers agreed.

A majority of the members of the households and all the forest officers agreed that reduction on the biodiversity loss was one of the EbA initiatives implemented in the Kakamega Tropical Rainforest ecosystem. This shows that reduction of biodiversity loss was one of the EbA initiatives in the area.

When members of the households were asked their opinion, if the forest ecosystem helped to adapt or mitigate climate change, a majority of the members of the households and forest officers agreed.

5.1.5 Challenges and Constraints Facing Implementation of EbA Initiatives in Kakamega Tropical Rainforest Ecosystem

In reference to continued uncertainties around future climate change, a majority of the members of the households agreed, while a majority of the forest officers disagreed. This shows that there were differences in opinion between the two sets of respondents.

In reference to high population growth rate as one of the constraints or challenges facing the implementation of EbA initiatives, a majority of both the household members and the forest officers agreed.

In relation to deforestation as one of the challenges facing the implementation of EbA initiatives in Kakamega Tropical Rainforest ecosystem, a majority of the members of the households and all the forest officers agreed that deforestation was a challenge facing implementation of EbA initiative in the forest ecosystem.

A majority of the members of the households disagreed, while a majority of the forest officers agreed that poverty was one of the challenges facing implementation of EbA initiatives in the forest ecosystem.

When the members of the households were asked if economic reasons like fluctuation of the market was another challenge, a majority of the members of the household and forest officers agreed to this statement.

A majority of the household members disagreed, while a majority of the forest officers agreed that physical reasons like remoteness was a challenge in the forest ecosystem. This shows that there was a disagreement between the two groups of respondents with the members of the households disagreeing while the forest officers agreeing with the statement.

A majority of the members of the households and the forest officers agreed that social political reasons were one of the challenges facing the forest ecosystem. This shows that social political reasons were among the challenges facing the forest ecosystem.

The respondents were asked to suggest ways in which the national and county governments could have lasting solutions to the effects of climate change on Kakamega tropical rainforest ecosystem. Among the members of the households, a majority said that the management should allow the residents to benefit, followed by those who said that the government should control the movement of animals, then followed by those who said that the government should formulate relevant policies to check the ecosystem and the lastly those who suggested that the forest should be guarded using an electric fence.

On the other hand, when the forest officers were asked to give similar suggestions, a majority also said that the residents should benefit, followed by those who argued that the government should control the movement of animals and only one of them suggested that the forest be guarded by the use of the electric fence. This shows therefore that both categories of respondents are of the idea that residents living around the forest ecosystem should be asked to help in conservation matters and at the same time benefit from the forest ecosystem.

5.2 Conclusions

1. This study concluded that Spatial and Temporal Characteristics of Climate Change were very extreme temperatures and precipitation. Majority of the respondents had witnessed climate change in the area.
2. Kakamega Tropical Rainforest is a source of many ecosystem services to the surrounding community; timber, firewood, herbal medicine, fodder for livestock, prevent storms, control floods, cloud formation and greenhouse gas regulation.
3. The impact of climate change on Kakamega Tropical Rainforest Ecosystem were changes in productivity, functional traits composition, changes in precipitation and warming, species extinction or range redistribution. However, there was disagreement to some extent on whether the increased fire frequency was indeed an impact on the forest ecosystem.
4. Ecosystem based adaptation measures are services used to attain or support adaptation to climate change. Another initiative was restoration of the highly degraded dry forest, reduction on the biodiversity loss was also one of the EbA initiatives implemented in the Kakamega tropical rainforest ecosystem, the forest ecosystem also helped to adapt or mitigate climate change.
5. High population growth rate, uncertainties around future climate change, deforestation, poverty, economic reasons like fluctuation of markets are some of the constraints or challenges facing the implementation of EbA initiatives.

5.3 Recommendations

1. There is need for afforestation and conservation of the Kakamega Tropical Rainforest so that we can get rid of very extreme temperatures and very extreme precipitation since many respondents had witnessed climate change in the area due to the destruction of the ecosystem.
2. There is need to conserve the Kakamega Tropical Rainforest as it is a source of many services to the surrounding community such as timber, firewood, herbal medicine, fodder for livestock, prevents storms, control floods, cloud formation and greenhouse gas regulation.
3. There is need to conserve Kakamega Tropical Rainforest Ecosystem to get rid of changes in productivity, functional traits composition, changes in precipitation and warming, species extinction or range redistribution.
4. The organizations responsible such as KFS ought to take the Ecosystem based adaptation measures to attain or support adaptation to climate change such as restoration of the highly degraded dry forest, reduction on the biodiversity loss was one of the initiatives implemented in the Kakamega tropical rainforest ecosystem, the forest ecosystem also helps to adapt or mitigate climate change.
5. The government need to address the challenges facing the implementation of EbA initiatives in Kakamega Tropical Rainforest Ecosystem such as High population growth rate, uncertainties around future climate change, deforestation, poverty, economic reasons like fluctuation of markets etc.

5.4 Suggestions for Further Research

To further understand the Impact of Climate Change on forest ecosystems in Kenya with emphasis to application of EbA to climate change in Kakamega Tropical Rainforest Ecosystem, the study suggests areas for further research that may provide more insights on the successes and challenges and lessons learned such as:

1. This study can be replicated in the other forest ecosystems with similar characteristics in Kenya and the world.
2. A study on the effects of Forest destruction on the social-economic conditions of the neighboring communities.

REFERENCES

Adame, M.F., Virdis, B., and Lovelock, C.E. (2010) Effect of geomorphological setting and rainfall on nutrient exchange in mangroves during tidal inundation. *Marine and Freshwater Research* 61, 1197-1206.

Adams, W.M. & Redford, K.H. (2009): Ecosystem Services and Conservation: Reply to Skrochand López-Hoffman; In: *Conservation Biology*, Volume 24, No. 1, pp. 328-329

Adger, W.N., Agrawal, S., and Mirza, M.M.W.(2007) Assessment of adaptation practices, options, constraints and capacity. *Climate change*: impacts, adaptation and vulnerability

Ahmmad, R., Nandy, P. & Husnain, P. (2013) Unlocking Ecosystem-based adaptation opportunities in coastal Bangladesh; In: *J Coast Conderv* (2013) 17; pub. Springer, pp. 833-840

Alamgir, M., Pert, P.L., &Turton, S.M. (2014) A review of ecosystem services research in Australia reveals a gap in integrating climate change and impacts on ecosystem services. *International Journal of Biodiversity Science, Ecosystem Services & Management* 10, 112-127.

Alkama, R., and Cescatti, A. (2016) Biophysical climate impacts of recent changes in global forest cover. *Science* 351:600–604.

Altieri,M.A.andNicholls,C.I.(2017),“Theadaptationandmitigationpotentialoftraditionalagricultureinachangingclimate”,*ClimaticChange*,Vol.140No.1,pp.33-45.

Anderson-Teixeira, K.J., Snyder, P.K., Twine, T.E., Cuadra, S.V., Costa, M.H. & DeLucia, E.H. (2012) Climate-regulation services of natural and agricultural ecoregions of the Americas. *NatureClim. Change* 2, 177-181.

Ayers, J.M. & Huq, S. (2009) The value of linking mitigation and adaptation: A case study of Bangladesh. *Environmental Management* 43(5):753-764.

Babar, S.F. and Ramesh, H. (2013), “Analysis of South West monsoon rainfall trend using statistical techniques over Nethravathi basin”, *International Journal of Advanced Technology in CivilEngineering*,Vol.2,pp.130-136.

Babulo, B., Muys, B., Fredu, N., Tollens, E., Nyssen, J., Deckers, J. &Mathijs, E. (2009) The economic contribution of forest resource use to rural livelihoods in Tigray, Northern Ethiopia. *Forest Policy and Economics* 11: 109–117.

Baral, H., Keenan, R.J., Sharma, S.K., Stork, N.E. &Kasel, S. (2014) Spatial assessment and mapping of biodiversity and conservation priorities in a heavily modified and fragmented production landscape in north-central Victoria, Australia. *Ecological Indicators* 36, 552-562.

Barasa, B.M.O., Oteng'i, S.B.B. and Wakhungu, J.W. (2015), "Impacts of climate variability in agricultural production in Kakamega county, Kenya", International Journal of Agriculture Innovations and Research, Vol. 3 No. 6, pp. 1638-1647

Barbosa, H.A., and Lakshmi Kumar, T.V., (2011) "What do vegetation indices tell us about the dynamics of the Amazon evergreen forests?" Anais XV-SBSR, Curitiba, PR, Brasil, 30 April to5 May 2011, INPE, p. 6488.

Bassiouni, M., & Oki, D. S. (2013). Trends and shifts in stream flow in Hawai'i, 1913-2008. *Hydrological Processes*, *27*(10), 1484–1500. doi:10.1002/hyp.9298

Bennett, E.M., Peterson, G.D. &Gordon, L.J. (2009) Understanding relationships among multiple ecosystem services. *Ecology Letters* 12, 1394-1404.

Bennun, A.L. &Njoroge P. (1999). *Important Birds Areas in Kenya*.East Africa Natural History Society, Nairobi, Kenya.

Boon, E. and Ahenkan, A. (2011), "Assessing climate change impacts on ecosystem services andlivelihoodsinGhana:casestudyofcommunitiesaroundSuiforestreserve",*JournalofEcosystemandEcography*,doi:10.4172/2157-7625.S3-001.

Bormann, B.T., Martin, J.R., Wagner, F.H., Wood, G.W., Alegria, J., Cunningham, P.G., Brookes, M.H., Friesema, P., Berg, J. & Henshaw, J.R. (1999) Adaptive management. In: Johnson, N.C.; Malk, A.J.; Sexton, W.T.; Szaro, R., eds. *Ecological stewardship: a common reference for ecosystem management*. Oxford, United Kingdom: Elsevier Science Ltd.: 505-534. Vol. 3.

Bourne, A., Holness, S.,& Holden, P. (2016) A socio-ecological approach for identifying and contextualising spatial ecosystem-based adaptation priorities at the sub-national level.

Brekke, L. D., Kiang, J. E., Olsen, J. R., Pulwarty, R. S., Raff, D. A., Turnipseed, D. P., Webb, R. S. &White, K. D. (2009)*Climate Change and Water Resources Management: A Federal Perspective*. Circular 1331 U.S. Department of the Interior, U.S. Geological Survey.

Brienen, R. J. W., Phillips,O. L.,Feldpausch,T. R., Gloor,E., Baker,T. R., Lloyd,J., Lopez-Gonzalez,G. & Moneagudo-Mendoza,A. (2015) Long-term decline of the Amazon carbon sink. Nature 519:344–348.

Brink, E., Aalders, T. & Ádám, D. (2016) Cascades of green: A review of ecosystem-based adaptation in urban areas. *Global Environmental Change* 36: 111-123.

Brown, H.C. & Lassoie, J.P. (2010). The interaction between market forces and management systems: a case study of non-wood forest products in the humid forest zone of Cameroon. *International Forestry Review* 12(1):13-26.

Bryan, B.A., Crossman, N.D., King, D. &Meyer, W.S. (2011) Landscape futures analysis: Assessing the impacts of environmental targets under alternative spatial policy options and future scenarios. *Environmental Modelling and Software* 26, 83-91.

Bryan, E., Claudia R., Barrack, O., Carla R., Silvia, S. and Mario, H.(2013) “Adapting Agriculture to Climate Change in Kenya: Household Strategies and Determinants.” *Journal ofEnvironmentalMangement*114: 26–35.

Burkhard, B., Kroll, F., Nedkov, S. &Müller, F. (2012) *Mapping ecosystem service supply, demand and budgets.* Ecological Indicators 21, 17-29.

Bussey, M., Carter, R.W., Keys, N., Carter, J., Mangoyana, R., Matthews, J., Nash, D., Oliver, J., Richards, R., Roiko, A., Sano, M., Thomsen, D.C., Weber, E. &Smith, T.F. (2012) Framing adaptive capacity through a history-futures lens: Lessons from the South East Queensland Climate Adaptation Research Initiative. *Futures* 44, 385-397.

Butler, R.A. (2009) "Impact of Population and Poverty on Rainforests". *Mongabay.com / APlace Out of Time: Tropical Rainforests and the Perils They Face*.

Camberlin, P. and Philippon, N. (2002), “The East African March–May rainy season: associatedatmosphericdynamicsandpredictabilityoverthe1968-97period”,*JournalofClimate*,Vol.15No.9,pp.1002-1019.

Campbell, J. (2002) Conservation Narratives in Costa Rica: Conflict and Co-existence

Canadell, J. G., and Schulze, E.D. (2014) Global potential of biosphericcaron management for climate mitigation. *Nature communications* 5:5282.

Carpenter, S.R., Mooney, H.A., Capistranod, J.A.D., DeFriese, R.S., Diazf, S., Dietz, T., Duraiappahh, A.K., Oteng-Yeboah, A., Pereira, H.M., Perringsk, C., Reid, W.V., Sarukhanm, J., Scholesn, R.J.&Whyte, A. (2009) Science for managing ecosystem services: Beyond the Millennium Ecosystem Assessment. Proceedings of the National Academy of Sciences of the United States of America 106, 1305-1312.

Carrasco, L.R., Papworth, S.K. (2014) A ranking of net national contributions to climate change mitigation through tropical forest conservation. *Journal of Environmental Management* 146,575-581.

CBD (Convention of Biological Diversity) (2009) “Connecting biodiversity and climate change mitigation and adaptation: Report of the Second Ad Hoc Technical Expert Group on Biodiversity and Climate Change.” Technical Series No. 41.Secretariat of the CBD, Montreal.

CBD (Convention on Biological Diversity) (2010) X/33 Biodiversity and climate change, Decision Adopted by the Conference of the Parties to the Convention on Biological Diversity at its Tenth Meeting; UNEP/CBD/COP/DEC/x/33; 29 October 2010. Nagoya, Japan: Secretariat of Convention on Biological Diversity.

Chenand, C. (2014) Trends in precipitation extremes during the typhoon season in Taiwan over the last 60 years. Atmospheric Science Letters. Wiley Online Library.

Chong, J. (2014) Ecosystem-based approaches to climate change adaptation: progress and challenges; In: *Int Environ Agreements,* 14, pp. 391-405

Chu, P.S., Chen, Y. R., & Schroeder, T. A. (2010) Changes in Precipitation Extremes in the Hawaiian Islands in a Warming Climate. *Journal of Climate*, *23*(18), 4881–4900. doi:10.1175/2010JCLI3484.1

Clark, J.S., Bell, D.M.,Hersh,M.H.,Kwit, M.C., Moran,E., Salk,C., Stine,A. & Valle,D. (2011) Individual-scale variation, species-scale differences: inference needed to understand diversity. *Ecology letters* 14:1273–87.

Colls, A., Ash,N. &Ikkala, N. (2009) “Ecosystem-based Adaptation: A natural response to climate change.” Gland, Switzerland: IUCN.

Collier, P., Conway, G. and Venables, T. (2008) Climate change and Africa. *Oxford Review of Economic Policy* vol. 24(2), pp. 337-353.

Costanza, R., De Groot, R., &Braat, L. (2017) Twenty years of ecosystem services: How far have we come and how far do we still need to go? *Ecosystem Services* 28: 1-16.

Creswell, J.W. and Miller, S. (2005).*Determining Validity in Qualitative Inquiry*.

Crossman, N.D., Bryan, B.A., &King, D. (2011) *Contribution of site assessment toward prioritizing investment in natural capital*.Environmental Modelling and Software 26, 30-37.

De Groot, R.(2010). Global estimates of the value of ecosystems and their services in monetary units.

Deng, S., Shi, Y., Jin, Y. &Wang, L. (2011) A GIS-based approach for quantifying and mapping carbon sink and stock values of forest ecosystem: A case study. *Energy Procedia*,1535-1545.

Denton, F.(2014) "Climate-resilient pathways: adaptation, mitigation, and sustainable development. "*Climate change:* 1101-1131.

Ding, H. &Nunes, P.A.L.D. (2014) Modeling the links between biodiversity, ecosystem services and human wellbeing in the context of climate change: Results from an econometric analysis of the European forest ecosystems. *Ecological Economics* 97, 60-73.

Doswald, N., Munroe, R., Roe, D., Giuliani, A., Castelli, I., Stephens, J., Möller, I., Spencer, T., Vira, B. &Reid, H. (2014) Effectiveness of ecosystem-based approaches to adaptaion: review of the evidence-base, In; *Climate and Development,* 6:2, pp.185-201

Dube, T., Moyo, P., Ncube, M., Madubula, N., Ngwenya, H., Zinyengere, N., Zhou, L., Francis, J.,Mthunzi, T., Olivier, C. and Madzivhandila, T. (2016), "The impact of climate change on agro-ecological based livelihoods in Africa: a review", *Journal of Sustainable Development*, Vol. 9No.1,pp.256-267.

EC (2013) *An EU strategy on adaptation to climate change.* Brussels: European Commission.

EC (2015) Towards an EU research and innovation policy agenda for nature-based solutions & renaturing cities. Final report of the Horizon 2020 expert group on nature-based solutions and re-naturing cities. Brussels: European Commission.

Egoh, B., Reyers, B., Rouget, M., Bode, M. &Richardson, D.M. (2009) Spatial congruence between biodiversity and ecosystem services in South Africa. *Biological Conservation* 142, 553-562.

Egoh, B. (2008)*Mapping ecosystem services for planning and management.*

Egoh, B., Rouget, M., Reyers, B., Knight, A.T., Cowling, R.M., Van-Jaarsveld, A.S. & Welz, A. (2007) Integrating ecosystem services into conservation assessments: A review. *Ecological Economics* 63, 714-721.

Egoh, B.N., Reyers, B., Carwardine, J., Bode, M., O'Farrell, P.J., Wilson, K.A., Possingham, H.P., Rouget, M., De Lange, W., Richardson, D.M. &Cowling, R.M. (2010).Safeguarding biodiversity and ecosystem services in the Little Karoo, South Africa.*Conservation Biology* 24, 1021-1030.

Eigenbrod, F., Armsworth, P.R., Anderson, B.J., Heinemeyer, A., Gillings, S., Roy, D.B., Thomas, C.D. &Gaston, K.J. (2010) *Error propagation associated with benefits transfer-based mapping of ecosystem services.* Biological Conservation 143, 2487-2493.

Enquist, B. J., and Enquist, C.A.F. (2011) Long-term change within a Neotropical forest: assessing differential functional and floristic responses to disturbance and drought. Global Change Biology 17:1408–1424.

Epple, C. and Dunning, E. (2014) "Ecosystem resilience to climate change: What is it and how can it be addressed in the context of climate change adaptation?" Technical report for the Mountain EbA Programme. UNEP World Conservation Monitoring Centre, Cambridge.

Estrella, M., Renaud, F.G., Karen S.R. & Udo, N. (2016) Defining New Pathways for Ecosystem-Based Disaster Risk Reduction and Adaptation in the Post-2015 Sustainable Development Agenda, in: Ecosystem- Based Disaster Risk Reduction and Adaptation in Practice. Springer International Publishing Switzerland,Chapter24:pp.553–591

Estrella, M.&Saalismaa, N. (2013).The Role of Ecosystems in Disaster Risk Reduction. United Nations University Press.

Evans, L.S., Hicks, C.C., &Cohen, P.J. (2015) Understanding leadership in the environmental sciences. *Ecology and Society* 20: 50.

Falkland, A. (1999) Tropical island hydrology and water resources: Current knowledge and future needs. Paper presented. *2nd International Colloquium on Hydrology and Water Management in the Humid Tropics*. Panama, Rep. of Panama. UNESCO-IHP. 22-26 March, 1999.

FAO (2010), Global Forest Resources Assessment, Food Agriculture Organization of the United Nations (FAO), Rome

FAO (2016) Forests and poverty reduction. Retrieved March 14, 2016.http://www.fao.org/forestry/livelihoods/.http://www.fao.org/forestry/livelihoods/en/.

Feeley, K. J., Davies, S. J., Perez, R., Hubbell,S. P. and Foster, R. B. (2011) Directional changes in the species composition of a tropical forest. *Ecology* 92:871–82.

FEWS NET (2013) "Food Security Brief," no. September 2009: 1–52.

Fisher, B. (2008) Global mapping of ecosystem services and conservation priorities.

Fisher, B., Turner, R.K. &Morling, P. (2009) *Defining and classifying ecosystem services for decision making.* Ecological Economics 68, 643-653.

Folke, C., Carpenter, S.R. &Walker, B. (2010) Resilience thinking: integrating resilience, adaptability and transformability. *Ecology and Society* 15.

FRA (2010) Global Forest Resources Assessment.

Geneletti, D. & Zardo, L. (2016) Ecosystem-based adaptation in cities: An analysis of European urban climate adaptation plans. *Land Use Policy* 50: 38-47.

George, S.J., Harper, R.J., Hobbs, R.J. &Tibbett, M. (2012) *A sustainable agricultural landscape for Australia: A review of interlacing carbon sequestration, biodiversity and salinity management in agroforestry systems.* Agriculture, Ecosystems and Environment 163, 28-36.

Giambelluca, T.W., Diaz, H.F. & Luke, M.S.A. (2008) Secular temperature changes in Hawai'i. *Geophysical Research Letters*, *35*(12).

Glick, P., Chmura, H. & Stein, B.A. (2011) Moving the Conservation Goalposts: a review of climate change adaptation literature. National Wildlife Federation, pp25

Gohler, D., Muller, F., Mytanz, C., Oliver, J., Renner, I., Riha, K. & Tscherning, K. (2013) Ecosystem Based Adaptation (EbA); pub. Deutsche Gesellschaft fürInternationale Zusammenarbeit (GIZ)

GoK (2012) "Seeds and plant varieties Act Chapter 326", 1-194, Kenya law reports. http://www.kenyalaw.org/klr/fileadmin/pdfdownloads/Acts/SeedsandPlantVarietiesActCap326.pdf

GoK (2013) Climate Risks, Vulnerability and Governance in Kenya.

Goodman, R.C., and Herold, M. (2014). Why maintaining tropical forests is essential and urgent for a stable climate. CGD climate and forest paper series 11.

Goosse H., Barriat, P.Y., Lefebvre, W., Loutre, M.F., Zunz, V., (2010) Introduction to climate dynamics and climate modeling. Online textbook available at http://www.climate.be/textbook.

Harrison, P.A., Berry, P.M., Simpson, G., Haslett, J.R., Blicharska, M., Bucur, M., Dunford, R., Egoh, B., Garcia-Lommelen, E., Meiresonne, L., Turkelboom, F. (2014) *Linkages between biodiversity attributes andecosystem services: A systematic review.* Ecosystem Services 9, 191-203.

Hawaii County Plan (2010) Plans - 2010 - 2012 County of Hawai'i Annual Plan for Workforce Investment Act of 1998

Hawaii County Water Use and Development Plan (2010).

Hector, A., Hautier,Y., Saner,P., Wacker, L., Bagchi,R., Joshi,J., Scherer-Lorenzen, M. Spehn, E.M. (2010) General stabilizing effects of plant diversity on grassland productivity through population asynchrony and over-yielding. Ecology 91:2213–2220.

Heltberg, R., Siegel, P.B. & Jorgensen, S.L. (2009) Addressing human vulnerability to climate change: Towards a no-regret approach. *Global Environmental Change* 19(1):89-99.

Hérault, B., Bachelot, B., Poorter, L., Rossi, V., Bongers, F., Chave, J., Paine,C.E.T. Wagner,F.(2011) Functional traits shape ontogenetic growth trajectories of rain forest tree species. Journal of Ecology 99:1431–1440.

Hertel, T.W., Burke, M.B. & Lobell, D.B. (2010) The poverty implications of climate-induced crop yield changes by 2030. Global Environmental Change.

Hilborn, R. (1992) Institutional learning and spawning channels for sockeye salmon (Oncorhynchus nerka).Canadian Journal of Fisheries and Aquatic Sciences. 49: 1126–1136.

Holland, M.B. (2012) Mesoamerican biological corridor. Chapter 5. In: Hilty JA, Chester CC, Cross M (eds) Climate and conservation: landscape and seascape science, planning and action. Island Press/Center for Resource Economics, Washington, pp. 92–103Google Scholar

Holling, C.S. (1978) Adaptive environmental assessment and management. London: John Wiley.

Huq, N., Renaud, F., & Sebesvari, Z. (2013) Ecosystem based adaptation to climate change – Integrating actions to sustainable adaptation. United Nations University, Institute for Environment and Human Security (UNU-EHS). Retrieved from: http://www.climate- impacts-2013.org/files/cwi_huq.pdf.

Imbach, P., Molina, L., Locatelli, B., Roupsard, O., Mahe, G., Neilson. R., Corrales, L., Scholze, M.,Ciais, P. (2012) Modeling potential equilibrium states of vegetation and terrestrial water cycle of Mesoamerica under climate change scenarios. J Hydrometeor 13:665–680.doi: 10.1175/JHM-D-11-023.1

IPCC (2007*) Climate Change 2007: Synthesis Report*, Geneva, Switzerland, p. 73.

IPCC (2012), “Managing the risks of extreme events and disasters to advance climate change adaptation”, in Field, C.B., Barros, V., Stocker, T.F. et al. (Eds), A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge.

IPCC (2013) Climate change: the physical science basis. Contribution of working group I to the fifth assessment report of the intergovernmental panel on climate change. Cambridge University Press, Cambridge.

IPCC (2014) *Summary for Policymakers, in the Field*, *Climate Change: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects.* Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change. Cambridge University Press, Cambridge, United Kingdom, and New York, NY, USA, pp. 1-32.

Johnson, G.W., Bagstad, K.J., Snapp, R.R., Villa, F. (2012) Service Path Attribution Networks (SPANs): A Network Flow Approach to Ecosystem Service Assessment. *International Journal of Agricultural and Environmental Information Systems*

Jones, H. P., Hole, D. G., & Zavaleta, E.S. (2012) Harnessing Nature To Help People Adapt To Climate Change. *Nature Climate Change*, *2*(7), 504-509.

Joppe, M. (2000) The Research Process. Retrieved December 16, 2006, from http://www.ryerson.ca/~mjoppe/rp.htm

Kabubo, M.J., and Kabara, M. (2015) “Climate Change and Food Security in Kenya.” *Environment for Development*.

Kakamega Forest Ecosystem Management Plan (KFEMP) (2012) Kakamega forest ecosystem management plan (2012-2022).

Kalacska, M., Sanchez-Azofeifa, G.A., Rivard, B., Calvo-Alvarado, J.C., Quesada, M. (2008) Baseline assessment for environmental services payments from satellite imagery: A case study from Costa Rica and Mexico. Journal of Environmental Management 88,348-359.

Karmalkar, A.V., Bradley, R.S. &Diaz, H.F. (2011) Climate change in central America and Mexico: regional climate model validation and climate change projections. ClimDyn 37:605–629. doi: 10.1007/s00382-011-1099-9

Kerlinger, F.N. (1983) Foundations of Behavioral Research. Surjeet Publications

Kithiia, S.M. (2011). "Sediment yields and transport within the Nairobi River basins, Kenya." In: River, Coastal and Estuarine Morphodynamics: RCEM2011. Tsinghua University, Beijing.

Klein, J., Juhola, S. and Landauer, M. (2017) Local authorities and the engagement of private actors in climate change adaptation. *Environment and Planning C: Politics and Space* 35: 1055-1074.

KNBS (2019) Kenya Census Report

Kombo, D. K., & Tromp, D. L. (2006). Proposal and thesis writing: An introduction.Nairobi:Paulines Publications

Kusel, J., Doak, S.C., Carpenter, S. & Sturtevant, V.E. (1996) Therole of the public in adaptive ecosystem management. In: Sierra Nevada ecosystem project: final report to Congress. Vol. II, assessments and scientific basis for management options. Davis, CA: University of California, Centers for Water and Wildland Resources: 611-624.

Lau,K.M.andWu,H.T.(2007),“Detectingtrendsintropicalrainfallcharacteristics,1979-2003”,*InternationalJournalofClimatology*,Vol.27No.8,pp.979-988.

Lee, K.N. (1993) Compass and gyroscope: integrating science and politics for the environment. Washington, DC: Island Press.

Leeuwen, V. & Marco, H.D. (2011)Towards a new crown indicator: An empirical analysis. Scientometrics. 2011;87:467–481. doi: 10.1007/s11192-011-0354-5.

Lemos, M.C.,Lo, Y.J., Nelson,D.R.&Eakin,H.(2016): *"Linking development to climate adaptation: leveraging generic and specific capacities to reduce vulnerability to drought in NE Brazil."* Global Environmental Change 39 170-179.

Lewis, S. L., Lopez-Gonzalez,G., Sonke,B.,Affum-baffoe,K., Baker, T. R., Lewis,S. L., Lopez-gonzalez,G.,Sonke,B. (2009) Increasing carbon storage in intact African tropical forests. Nature 457:1003–1006.

Li, S., Wu, X., Xue, H., Gu, B., Cheng, H., Zeng, J., Peng, C., Ge, Y. &Chang, J. (2011)*Quantifying carbon storage for tea plantations in China*. Agriculture, Ecosystems and Environment 141, 390-398.

Liu, Y.Y., Van Dijk, A.I.J.M., de Jeu, R.A.M., Canadell, J.G., McCabe, M.F., Evans, J.P.&Wang, G. (2015) *Recent reversal in loss of global terrestrial biomass.* Nature Clim. Change 5, 470-474.

Lo, V. (2016) Synthesis Report on Experiences with Ecosystem-Based Approaches to Climate Change Adaptation and Disaster Risk Reduction. Secretariat of the Convention on Biological Diversity.

Lyra, A.A., Chou, S.C., Sampaio, G.O. (2016) Sensitivity of the Amazon biome to high resolution climate change projections. Acta Amazonica 46:175–188. doi: 10.1590/1809-4392201502225

MA (2005*) Ecosystems and Human Well-being*: A Framework for Assessment, Island Press, Washington DC.

MA (2003) Ecosystems and Human Well-being: A Report of the Conceptual Framework Working Group of the Millennium Ecosystem Assessment

Malhi, Y., Aragao, L.E.O.C., Galbraith, D., Huntingford, C., Fisher, R.&Zelazowski, P. (2009) Exploring the likelihood and mechanism of a climate-change-induced dieback of the Amazon rainforest.

Malhi, Y. (2012) The productivity, metabolism and carbon cycle of tropical forest vegetation. *Journal of Ecology* 100:65–75.

Malhi, Y., Gardner, T. A., Goldsmith, G. R., Silman, M. R. and Zelazowski, P. (2014) Tropical forests in the Anthropocene. Annual Review of Environment and Resources 39:125–159.

Maraseni, T.N. (2012) "Climate change, poverty and livelihoods: adaptation practices by rural mountain communities in Nepal." Environmental science & policy 21: 24-34.

Martin, A., Andrew, B. and Jan, B. (2010) "Ecosystem services and poverty alleviation: assessing the constraints and opportunities." 99-104.

Martin, S. (2011) “Ecosystem-based Adaptation: What does it really mean?” Climate Prep: Adaptation stories, lessons, and explorations.

Mayers, R. E. (2009). Multimedia learning (2nd ed). New York: Cambridge University Press.

McBreen, J. (2016) Regional Assessment on Ecosystem-based Disaster Risk Reduction and Biodiversity in South America.

Mercer, J., Kelman, I., Afthan, B. & T. Kurvits (2012) Ecosystem-based adaptation to Climate Change in Caribbean Small Island Developing Stats: Integrating Local and External Knowledge; In: Sustainability, Vol. 4, pp. 1908-1932

Milman, A. and Jagannathan, K. (2017) Conceptualization and implementation of ecosystems-based adaptation. *Climatic Change* 142: 113-127.

Morin, X., Fahse,L., De Mazancourt,C., Scherer-Lorenzen,M. and Bugmann,H. (2014) Temporal stability in forest productivity increases with tree diversity due to asynchrony in species dynamics. Ecology Letters 17:1526–1535.

Mugenda, G.A. (2008). Social science research: Theory and principles. Nairobi, Kenya: Applied Research and Training Services.

Mugenda, A. and Mugenda, O. (2010). Research methods: Quantitative and qualitative approaches. Nairobi: ACTS Press.

Mulinya,C.,Ang'awa,F.andTonui,K.(2016),"Constraintsfacedbysmallscalefarmersinadaptingtoclimatechangein Kakamegacounty",*InternationalOrganizationofScientificResearch-JournalofHumanitiesandSocialScience*,Vol.21No.10,pp.8-18.

Mulinya, C. (2017), "Factors affecting small scale farmers coping strategies to climate change in Kakamega county in Kenya", International Organization of Scientific Research – Journal of Humanities and Social Science, Vol. 22 No. 2, pp. 100-109.

Munang, R., Thiaw, I., Alverson, K., Liu, J. & Han, Z. (2013) The role of ecosystem services in climate change adaptation and disaster risk reduction. Curr. Opin. Environ. Sustain. Terrestrial systems 5, 47–52. doi:10.1016/j.cosust.2013.02.00

Munang, R., & Han, Z. (2014) "*Harnessing ecosystem-based adaptation to address the social dimensions of climate change." Environment*: Science and Policy for Sustainable Development 56.1: 18-24.

Mutoko, M.C., Hein, L., Shisanya, C.A. (2015*) Tropical forest conservation versus conversion trade-offs: Insights from analysis of ecosystem services provided by Kakamega rainforest in Kenya*. Ecosystem Services 14, 1-11.

Mwendwa, P. and Richard A.G. (2012) "Climate Change Impacts and Adaptation Strategies in Kenya."*Chinese Journal of Population Resources and Environment* 10 (4): 22–29.doi:10.1080/10042857.2012.10685104.

Naidoo, R., Balmford, A., Costanza, R., Fisher, B., Green, R.E., Lehner, B., Malcolm, T.R. &Ricketts, T.H. (2008) *Global mapping of ecosystem services and conservation priorities.* Proceedings of the National Academy of Sciences of the United States of America 105, 9495-9500.

Naumann, S., Anzaldua, G., Berry, P., Burch, S., Mckenna D., Frelih-Larsen, A., Gerdes, H. & Sanders,M. (2011) Assessment of the potential of ecosystem-based approaches to climate change adaptation and mitigation in Europe. Final report to the European Commission, DG Environment, Contract no. 070307/2010/580412/SER/B2, Ecologic institute and Environmental Change Institute, Oxford University Centre for the Environment

Nelson, E., Mendoza, G., Regetz, J., Polasky, S., Tallis, H., Cameron, D.R., Chan, K.M., Daily, G.C., Goldstein, J., Kareiva, P.M., Lonsdorf, E., Naidoo, R., Ricketts, T.H. &Shaw, M.R. (2009) *Modeling multiple ecosystem services, biodiversity conservation, commodity production, and tradeoffs at landscape scales.* Front Ecol Environ 7, 4-11.

Nicholson, S.E., Davenport, M.L., Malo, A.R., (1990)The comparsion of the vegetation response to rainfall in the Sahel and East Africa, using normalized difference vegetation index from NOAA AVHRR. Climatic Change17, 209-241.

Nicholson, S.E. (2017), "Climate and climatic variability of rainfall over Eastern Africa", *Reviews ofGeophysics*,Vol.55No.3,pp.590-635.

Ninan, K.N. (2014) Valuing Ecosystem Services: Methodological Issues and Case Studies. Edward Elgar Publishing.

Nkem, J., Kalame, F.B., Idinoba, M., Somorin, O.A., Ndoye, O. &Awono, A. (2010) *Shaping forest safety nets with markets: Adaptation to climate change under changing roles of tropical forests in Congo Basin*. Environmental Science & Policy 13, 498-508.

Noble, I.R., Huq, S., &Anokhin, Y.A. (2014) Adaptation needs and options. *Climate Change: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change.* Cambridge University Press, Cambridge and New York.

Norrington, D.G. and Nigel, T.(2011) "Climate Change Financing and Aid Effectiveness Kenya Case Study,"

Ochenje, I.M., Ritho, C.N., Guthiga, P.M. and Mbatia, O.L.E. (2016), "Assessment of farmers to the effects of climate change on water resources at farm level: case study of Kakamega county, Kenya", Presented at the 5th International Conference of the African Association of Agricultural Economists, September 22 - 26, Addis Ababa.

Ofoegbu,C.,Chirwa,P.W.,Francis,J.andBabalola,F.D.(2016),"Perception-basedanalysisofclimatechange effect on forest-based livelihood: the case of Vhembe district in South Africa, Jamba",*JournalofDisasterRiskStudies*,Vol.8No.1,p.271.

Ojea, E. (2015) Challenges for mainstreaming Ecosystem-based Adaptation into the international climate agenda. *Current Opinion in Environmental Sustainability* 14: 41-48.

Okali, D. (2011), "Climate change and African moist forests in Chidumayo", in Okali, D.E., Kowero, G. and Larwanou, M. (Eds), Climate Change and African Forest and Wildlife Resources, African Forest Forum, Nairobi, pp. 68-84.

Olsson, O., Ekroos, J., Rundlöf, M., Watzold, F. and Smith, H.M..(2014) Social-ecological innovation and transformation. Pages 223-243 in A. Nicholls and A. Murdoch,editors. Social innovation: blurring boundaries to reconfigure markets. Palgrave MacMillan, Basingstoke, UK.

Ongong'a, I.A. and Sweta, L. (2014), "Land cover and land use mapping and change detection of Mau complex in Kenya using geospatial technology", International Journal Science Research, Vol. 3, pp. 767-778.

Orodho, A. J. (2003). *Essentials of educational and social sciences research method*. Nairobi: Masola Publishers.

Orodho, J.A.and Kombo,D.K. (2005).*Elements of Education and Social Science Research Methods*, Kanezja Publishers

Oxfam (2009) "Climate change and poverty- A case study from China." Derived from:http://www.greenpeace.org/china/Global/china/_planet-2/report/2009/6/poverty report2009.pdf.

Pahl-Wostl, C. (2009) A conceptual framework for analyzing adaptive capacity and multi-level learning processes in resource governance regimes. *Global Environmental Change*, 19(3):354-365.

Palomo, I., Martín-López, B., Potschin, M., Haines-Young, R., Montes, C. (2013)*National Parks, buffer zones and surrounding lands: Mapping ecosystem service flows*. Ecosystem Services 4, 104-116.

Paramova, P. & Herbert, B. (2012).Energy and Behavior: Towards a Low Carbon Future.Edited by Marta Lopes, Carlos Henggeler Antunes, Kathryn B. Janda

Paudyal, K., Baral, H., and Keenan, R.J. (2016) Local actions for the common good: Can the application of the ecosystem services concept generate improved societal outcomes from natural resource management? *Land Use Policy* 56: 327-332.

Persson, A., Klein, R.J.T., Siebert, C.K., Atteridge, A., Muller, B., Hoffmaister, J., Lazarus, M. & Takama, T. (2009) Adaptation finance under a Copenhagen agreed outcome. SEI, Stockholm.

Pert, P., Butler, J., Brodie, J., Bruce, C., Honzák, M., Kroon, F., Metcalfe, D., Mitchell, D., Wong, G. (2010) *A catchment-based approach to mapping hydrological ecosystem services using riparian habitat*: A case study from the Wet Tropics, Australia. Ecological Complexity 7, 378-388.

Pert, P.L., Hill, R., Maclean, K., Dale, A., Rist, P., Schmider, J., Talbot, L., Tawake, L. (2015)*Mapping cultural ecosystem services with rainforest aboriginal peoples: Integrating biocultural diversity, governance and social variation*. Ecosystem Services 13, 41-56.

Pittock, J., Cork, S., Maynard, S. (2012) *The state of the application of ecosystems services in Australia*. Ecosystem Services 1, 111-120.

Poorter, L., Van der Sande, M.T., Thompson,J.,Arets, E.J.M.M., Alarcón,A., Álvarez-Sánchez, J., Ascarrunz,N., Balvanera, P. (2015) Diversity enhances carbon storage in tropical forests. Global Ecology and Biogeography 24:1314–1328.

Poorter, L., Bongers,F.,Aide,T. M., Almeyda,A. M.Z., Balvanera, P., Becknell,J. M.,Boukili,V.&Brancalion, P.H.S., (2016) Biomass resilience of Neotropical secondary forests. Nature 530:211–214.

Posthumus, H., Rouquette, J.R., Morris, J., Gowing, D.J.G., &Hess, T.M. (2010) *A framework for the assessment of ecosystem goods and services; a case study on lowland floodplains in England*. Ecological Economics 69, 1510-1523.

Price, S.F., Catania, G.A., &Neumann, T.A.(2008) Characterizing englacial drainage in the ablation zone of the Greenland ice sheet.Volume 54, Issue 1872008, pp. 567-578

Ramirez-Villegas, J., Challinor, A.C., Thornton, P.K. and Jarvis, A. (2013), "Implications of regional improvement in global climate models for agricultural impacts research", Environmental Research Letters, Vol. 8 No. 2, p. 024018

Raven, J.A.,Handley, L.L., Austin, A.T., Robinson, D., Scrimgeour, C.M.,Heaton, T.H.E., Schmidt, S., and Stewart, G.R. (1999) The 15N natural abundance (δ15N) of ecosystem samples reflects measures of water availability

Reid, H. and Alam,S. (2014) "Ecosystem-based Approaches to Adaptation. Evidence from two sites in Bangladesh."Working Paper.IIED.

Reiss, J., Bridle,J. R., Montoya,J. M.and Woodward G. (2009) Emerging horizons in biodiversity and ecosystem functioning research. Trends in Ecology and Evolution 24:505–514.

Renaud, F., Sudmeier, K. and Estrella, M. (eds) (2013) "The Role of Ecosystems in Disaster Risk Reduction." Tokyo: United Nations University Press.

Renaud, F.G., Sudmeier-Rieux, K., Estrella, M., &Nehren, U., (2016) Ecosystem-Based Disaster Risk Reduction and Adaptation in Practice. Springer, Switzerland.

Rockstrom, J., Steffen, W., Noone,K., Persson, A., Chapin,F. S., Lambin,E. F., Lenton,T. M., Scheffer,M., (2009) A safe operating space for humanity. *Nature* 461:472–475.

Saatchi, S.S., Harris, N.L., Brown, S., Lefsky, M., Mitchard, E.T.A., Salas, W., Zutta, B.R.,Buermann, W., Lewis, S.L., Hagen, S., Petrova, S., White, L., Silman, M., Morel, A. (2011) *Benchmark map of forest carbon stocks in tropical regions across three continents*. Proceedings of the National Academy of Sciences 108, 9899-9904.

Safeeq, M., Mair, A., & Fares, A. (2013) Temporal and spatial trends in air temperature on the Island of Oahu, Hawaii. *International Journal of Climatology*, *33*(13), 2816–2835. doi:10.1002/joc.3629

Sakschewski, B., Von Bloh,W., Boit,A., Rammig, A., Kattge,J., Poorter,L., Penuelas,J. and Thonicke, K., (2015) Leaf and stem economics spectra drive diversity of functional plant traits in a dynamic global vegetation model. Global Change Biology 24:2711–2725.

Sarmiento,J.L., Hughes, T.M.C., Stouffer,R.J. and Manabe, S.(1998) Modelling regional responses by marine pelagic ecosystems to global climate change.

SBSTA. (2013) Report on the technical workshop on ecosystem-based approaches for adaptation to climate change. Bonn: Subsidiary Body for Scientific and Technological Advice, United Nations Framework Convention on Climate Change.

Scheufele, G. and J. Bennett. (2012). "Valuing ecosystem resilience." *Journal of Environmental Economics and Policy* 1(1): 18-31.

Secretariat of the Convention on Biological Diversity (2009) *Review of the Literature on theLinks between Biodiversity and Climate Change: Impacts, Adaptation, and Mitigation*. No. 42.UNEP/Earthprint.

Seppala, R., Buck, A. and Katila, P. (eds) (2009) *Adaptation of Forests and People to Climate Change – A Global Assessment Report*. IUFRO World Series volume 22, International Union of Forest Research Organisations, Vienna.

Seppelt, R., Dormann, C.F., Eppink, F.V., Lautenbach, S., Schmidt, S. (2011) A quantitative review of ecosystem service studies: approaches, shortcomings and the road ahead. *Journal of Applied Ecology* 48, 630-636.

Seppelt, R., Fath, B., Burkhard, B., Fisher, J.L., Grêt-Regamey, A., Lautenbach, S., Pert, P.,Hotes, S., Spangenberg, J., Verburg, P.H., Van Oudenhoven, A.P.E. (2012) *Form follows function? Proposing a blueprint for ecosystem service assessments based on reviews and case studies.* Ecological Indicators 21, 145-154.

Serdeczny, O., Adams, S., Baarsch, F., Coumou, D., Robinson, A., Hare, W., Schaeffer, M., Perrette, M. and Reinhardt, M. (2015), "Climate change impacts in Sub-Saharan Africa: from physical changes to their social repercussions", Regional Environmental Change, doi: 10.1007/10113-015-0910-2.

Shaw, M.R., Pendleton, L., Cameron, D.R., Morris, B., Bachelet, D., Klausmeyer, K.,MacKenzie, J., Conklin, D.R., Bratman, G.N., Lenihan, J. (2011) *The impact of climate change on California's ecosystem services*. Climatic Change.doi:10.1007/s10584-011-0313-4.

Shiferaw, A.(2011) Evaluating the land use and land cover dynamics in Borena Woreda of South Wollo highlands, Ethiopia. Journal of Sustainable Development in Africa13(1), 87-107.

Simelton,E.,Quinn,C.H.,Batisani,N.,Dougill,A.J.,Dyer,J.C.,Fraser,E.D.,Mkwambisi,D.,Sallu,S.andStringer, L.C. (2013), "Is rainfall really changing? Farmers' perceptions, meteorological data, andpolicyimplications",*ClimateandDevelopment*,Vol.5No.2,pp.123-138.

Simpson, R.D. (2011): The "Ecosystem Service Framework": A Critical Assessment; In: Ecosystem Services Economics – Working Paper Series, Division of Environmental Policy Implementation, Paper No. 5

Slik, J. W. F., Paoli, G., McGuire,K., Amaral,I., Barroso,J., Bastian,M., Blanc,L. & Bongers, F. (2013) Large trees drive forest aboveground biomass variation in moist lowland forests across the tropics. Global Ecology and Biogeography 22:1261–1271.

Smith, M.S.& Ash, A. (2011) *Adaptation: reducing risk, gaining opportunity*, in: Cleugh, H., Smith, M.S., Battaglia, M., Graham, P. (Eds.), Climate Change Science and Solution for Australia CSIRO Publishing, Victoria, Australia, pp. 59-72.

Sneyers,R.(1990),"Onthestatisticalanalysisofseriesofobservation",WMOTechnicalNoteNo.143,Vol.192,Geneva.

Solomon, S. (2007) Climate Change: The Physical Science Basis. Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller (Eds.), Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 996 pp.

State of Environment-India 2009

Steffen, W., Grinevald,J.,Crutzen,P. and McNeill, J., (2011) The Anthropocene: conceptual and historical. Philosophical Transactions of the Royal Society.

Steffen, W., Richardson, K., & Rockstrom, J., (2015). Planetary boundaries: Guiding human development on a changing planet.

Stephenson, N. L., Das,A.J., Condit,R., Russo,S.E.,Baker,P.J., Beckman,N.G.,Coomes, D.A. & Lines, E.R. (2014) Rate of tree carbon accumulation increases continuously with tree size. Nature 507:90–93.

Tanner, T. & Mitchell, T. (2008) Disaster risk reduction, climate change adaptation and human security.UNISDR.ORG.

TEEB (2009).The Economics of Ecosystems & Biodiversity.Pavan Sukhdev.

TEEB Foundation (2010) Integrating the ecological and economic dimensions in biodiversity and ecosystem service valuation.

TEEB Synthesis (2010) Valuing Nature Protected Areas and Ecosystem Services.

The New York Times 2009

Thomas W.H. & Rosch, D.S. (2010)Climate Change, Agriculture, and Poverty. https://doi.org/10.1093/aepp/ppq016

Thorlakson, T. and Henry, N. (2012) "Reducing subsistence farmers' vulnerability to climate change: evaluating the potential contributions of agroforestry in western Kenya." Agriculture & Food Security 1.1: 15.

Thornton, P.K., Ericksen, P.J., Herrero, M. and Challinor, A.J. (2014), “Climate variability and vulnerability to climate change: a review”, Global Change Biology, Vol. 20 No. 11, pp. 3313-3328.

Tompkins, E.L.,and Eakin, H. (2012) Managing private and public adaptation to climate change.*Global Environmental Change* 22: 3-11.

Travers, A., Elrick, C., Kay, R., Vestergaard, O., Olhoff, A., Mills, A., & Dews, G. (2012) Ecosystem-based adaptation guidance: moving from principles to practice. UNEP.

Turpie, J. and Visser, M. (2013), “The impact of climate change on South Africa’s rural areas”, in Financial and Fiscal Commission (Ed.), Submission for the 2013/14 Division of Revenue, Financial and Fiscal Commission, Cape Town, pp. 100-162.

UNCCD (1997) Conference of the parties (COP 1) held in Rome Report.

UNDP, United Nations Development Programme. (2015) "Generating multiple benefits from Ecosystem-based Adaptation in mountain ecosystems."

UNEP(2012). 21 Issues for the 21st Century: Result of the UNEP Foresight Processon Emerging Environmental Issues. Alcamo, J., Leonard, S.A. (Eds.). United Nations Environment Programme (UNEP), Nairobi, Kenya.

UNEP 2014 Annual Report

UNFCCC (2010) Climate Change: Impacts, Vulnerabilities and Adaptation in Developing Countries. United Nations Framework Convention on Climate Change (UNFCCC), Climate Change Secretariat, 68 pp., September 10.

UNFCCC (2011) Decision 1/CO.16 The Cancun Agreements: Outcome of the work of the Ad Hoc Working Group on Long-term Cooperative Action under the Convention, para 14.

United Nations Framework Convention on Climate Change (UNFCCC) (2013) Report on the technical workshop on ecosystem-based approaches for adaptation to climate change; Subsidiary Body for Scientific and Technological Advice (SBSTA), Thirty-eighth session, Bonn

United Nations (2015) New York "*The Millennium Development Goals Report 2015*"

United Nations (2015) Adoption of the Paris agreement. FCCC/CP/2015/L.9/Rev.1.

UNITED NATIONS ENVIRONMENT PROGRAMME (UNEP) (2013) The Emissions Gap Report 2013 – A UNEP Synthesis Report, Nairobi

UNISDR. (2009). Terminology UNISDR..

Uy, N. & Shaw R. (2012) The Role of Ecosystems in Climate Change Adaptation and Disaster Risk Reduction; In Ecosystem-based adaptation. *Community, Environment and Disaster Risk Management,* Vol. 12, pp. 41-59

Victor, D.G., Zhou, D., &Ahmed, E.H.M. (2014) Introductory Chapter. In *Climate Change: Mitigation of Climate Change. Contribution of Working Group III to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change*. Cambridge and New York: Cambridge University Press.

Vignola, R., Harvey, C.A., &Bautista-Solis, P. (2015) Ecosystem-based adaptation for smallholder farmers: Definitions, opportunities and constraints. *Agriculture, Ecosystems& Environment* 211: 126-132.

Walters, C.J. &Holling, C.S. (1990) Large-scale management experiments and learning by doing. *Ecology*. 71(6): 2060 – 2068

WMO (2011) Frequently Asked Questions (FAQs). World Meteorological Organization, Commission for Climatology.

World Bank (2009)Changing climate in Africa: A roadmap for action. The World Bank, Washington DC.

World Bank (2009) Convenient solutions to an inconvenient truth: Ecosystem-based approaches to climate change. World Bank, Washington, DC.

World Bank (2009).Roots for good governance – An analytical framework for governance reforms. Agriculture and Rural Development Department. World Bank.

World Bank (2014) "Turn Down the Heat: Confronting the New Climate Normal." Washington. DC: World Bank.

Yachi, S, &Loreau, M. (1999) Biodiversity and ecosystem productivity in a fluctuatingenvironment: The insurance hypothesis. Proc Natl Acad Sci USA 96: 1463-1468

Youn, C., Chandra, S., Fegraus, E.H., Lin, K., &Baru, C. (2011) *TEAM network: Building web-based data access and analysis environments for ecosystem services*. Procedia Computer Science 4, 146-155.

Zhong, L., Ma, Y., Salama, M., &Su, Z., (2010) Assessment of vegetation dynamics and their response to variations in precipitation and temperature in the Tibetan Plateau. Climatic change103, 519-535.

APPENDICES

Appendix I: Questionnaire for Heads of Households

IMPACT OF CLIMATE CHANGE ON FOREST ECOSYSTEMS IN KENYA: APPLICATION OF ECOSYSTEM BASED ADAPTATION TO CLIMATE CHANGE IN KAKAMEGA FOREST ECOSYSTEM

PREAMBLE

I am John Ayieko Aseta a lecturer at Kaimosi Friends University College (Constituent College of Masinde Muliro University of Science and Technology). I am a PhD candidate at Moi University Department of Geography. I am carrying out research on "Impacts of Climate Change on forest Ecosystems in Kenya: Application of Ecosystem Based Adaptation to Climate Change in Kakamega Forest Ecosystem." The researcher hopes that the findings of this study will help solve the problem, guide future policy and restore the confidence of people living in this area. You are one of the people selected to participate in this study. Your responses will be treated with confidentiality during and after the study and used solely for academic purpose. Your participation is highly appreciated.

SECTION A: RESPONDENTS IDENTIFICATION

1. Location ____
2. Distance from the Forest ____________________________________

SECTION B: DEMOGRAPHIC AND SOCIO-ECONOMIC CHARACTERISTICS

3. Gender of the respondent: Female □ Male □

4. Age of the respondent ____

5. Please mark the **highest** level of education reached by respondent:

i. Primary □

ii. Secondary □

iii. Tertiary □

iv. Others (specify)____

6. Please indicate the work you do

Peasant ☐ Civil servant ☐ Business person ☐ Large scale farmer ☐

Others ☐ specify ____

7. Income per Month ____

8. How long have you lived in this area?

Less than one year ☐ 1-5 years ☐ 6-10 years ☐ over 10 years ☐

SECTION C: SPATIAL AND TEMPORAL CHARACTERISTICS OF CLIMATE CHANGE IN KAKAMEGA TROPICAL RAINFOREST

Tick √ where necessary on the box provided.

9. What is Climate Change?

Responses	SA	A	UD	D	SD
Very extreme temperatures					
Very extreme precipitation					
Very extreme temperatures and precipitation					
Others (specify)					

SA - Strongly Agree, A- Agree, UN- Undecided, D- Disagree, SD - Strongly Disagree

10. Have you witnessed changes in the climate in the previous years in this area?

Yes ☐

No ☐

11. If yes, what are the visible changes for you?

Responses	SA	A	UD	D	SD
Shift in the rainy and dry season					
Droughts					
Intense rainfall					
Less rainfall					
Others (specify)					

SA - Strongly Agree, A- Agree, UN- Undecided, D- Disagree, SD - Strongly Disagree

SECTION D: ECOSYSTEM SERVICESOF KAKAMEGA TROPICAL RAIN FORESTOF KAKAMEGA COUNTY, KENYA

Tick √ where necessary on the box provided.

12. What are the Ecosystem services of Kakamega Tropical Rainforest?

Responses	**SA**	**A**	**UD**	**D**	**SD**
Source of timber					
Source of firewood					
Source of herbal medicine					
Source of fodder for livestock					
Source of food					
Prevents storms					
Flood control					
Cloud formation					
Greenhouse gas regulation					
Others (specify)					

SA - Strongly Agree, A- Agree, UN- Undecided, D- Disagree, SD - Strongly Disagree

SECTION E: IMPACTS OF CLIMATE CHANGE ON KAKAMEGA TROPICAL RAIN FOREST ECOSYSTEM

Tick √ where necessary on the box provided.

13. What are the impacts of climate change on Kakamega Tropical Rainforest?

Responses	**SA**	**A**	**UD**	**D**	**SD**
Changes in productivity					
Functional trait composition					
Species extinction or range redistribution					
Increased fire frequency					
Changes in precipitation and warming					
Others (specify)					

SA - Strongly Agree, A- Agree, UN- Undecided, D- Disagree, SD - Strongly Disagree

SECTION F: ECOSYSTEM-BASED ADAPTATION TO CLIMATE CHANGE IN KAKAMEGA TROPICAL RAIN FOREST

Tick √ where necessary on the box provided.

14. What is Ecosystem-Based Adaptation?

Responses	**SA**	**A**	**UD**	**D**	**SD**
Measures which use ecosystem services to attain or support adaptation to climate change.					
Others (specify)					

SA - Strongly Agree, A- Agree, UN- Undecided, D- Disagree, SD - Strongly Disagree

15. Which are the EbA initiatives implemented in Kakamega Tropical Rainforest?

Responses	**SA**	**A**	**UD**	**D**	**SD**
Policy and behavioural changes					
Targeted management					
Conservation activities					
Restoration of highly degraded dry forest					
Reducing biodiversity loss,					
Others (specify)					

SA - Strongly Agree, A- Agree, UN- Undecided, D- Disagree, SD - Strongly Disagree

16. Do you think that the forest help to adapt or mitigate climate change?

Yes ☐

No ☐

17. If Yes, specify____

____

SECTION G: CHALLENGES AND CONSTRAINTS FACING IMPLEMENTATION OF EBA INITIATIVES IN KAKAMEGA TROPICAL RAIN FOREST

Tick √ where necessary on the box provided.

18. What are the challenges and constraints facing implementation of EbA initiatives in Kakamega Tropical Rainforest?

Responses	**SA**	**A**	**UD**	**D**	**SD**
Continued uncertainties around future climate conditions					
Higher population growth rate					
Deforestation					
Poverty					
Economic reasons like the fluctuation of markets					
Physical reasons like remoteness					
Social-political reasons					
Others (specify)					

SA - Strongly Agree, A- Agree, UN- Undecided, D- Disagree, SD - Strongly Disagree

19. What advice can you give the national/county government to have a lasting solution to the effects of climate change on Kakamega Tropical Rain Forest Ecosystem? ____

____

Appendix II: Interview Schedule for Government Officials (Kenya Forest Service Officers)

IMPACT OF CLIMATE CHANGE ON FOREST ECOSYSTEMS IN KENYA: APPLICATION OF ECOSYSTEM BASED ADAPTATION TO CLIMATE CHANGE IN KAKAMEGA FOREST ECOSYSTEM

PREAMBLE

I am John Ayieko Aseta a lecturer at Kaimosi Friends University College (Constituent College of Masinde Muliro University of Science and Technology). I am a PhD candidate at Moi University Department of Geography. I am carrying out research on "Impacts of Climate Change on forest Ecosystems in Kenya: Application of Ecosystem Based Adaptation to Climate Change in Kakamega Forest Ecosystem. "This Interview Schedule is meant to elicit information, which will shed light on the same. You are therefore requested to carefully respond to these question items with utmost honesty. The information you provide is confidential and will not under any circumstance be divulged to any other person. Do NOT reveal your identity anywhere on this paper.

SECTION A: RESPONDENT IDENTIFICATION

1. Location ____
2. Distance from the Forest ________________________________

SECTION B: DEMOGRAPHIC AND SOCIO-ECONOMIC CHARACTERISTICS

Tick √ where necessary on the box provided.

3. Gender of the respondent: Female □ Male □

4. Age of the respondent____________________________________

5. Please mark the **highest** level of education reached by respondent:

i. Primary □

ii. Secondary □

iii. Tertiary □

iv. Others (specify)____

6. When were you appointed to this position? _______________________

7. How long have you lived in this area? ___________________________________

SECTION C: SPATIAL AND TEMPORAL CHARACTERISTICS OF CLIMATE CHANGE IN KAKAMEGA TROPICAL RAINFOREST

Tick √ where necessary on the box provided.

8. What is Climate Change?

Responses	SA	A	UD	D	SD
Very extreme temperatures					
Very extreme precipitation					
Very extreme temperatures and precipitation					
Others (specify)					

SA - Strongly Agree, A- Agree, UN- Undecided, D- Disagree, SD - Strongly Disagree

9. What are the spatial and temporal characteristics of climate change in Kakamega Tropical Rainforest?

Responses	**SA**	**A**	**UD**	**D**	**SD**
Shift in the rainy and dry season					
Droughts					
Intense rainfall					
Less rainfall					
Others (specify)					

SA - Strongly Agree, A- Agree, UN- Undecided, D- Disagree, SD - Strongly Disagree

SECTION D: ECOSYSTEM SERVICESOF KAKAMEGA TROPICAL RAIN FOREST

Tick √ where necessary on the box provided.

10. What are the Ecosystem services of Kakamega Tropical Rainforest?

Responses	**SA**	**A**	**UD**	**D**	**SD**
Source of timber					
Source of firewood					
Source of herbal medicine					
Source of fodder for livestock					
Source of food					
Prevents storms					
Flood control					
Cloud formation					
Greenhouse gas regulation					
Others (specify)					

SA - Strongly Agree, A- Agree, UN- Undecided, D- Disagree, SD - Strongly Disagree

SECTION E: IMPACTS OF CLIMATE CHANGE ON KAKAMEGA TROPICAL RAINFOREST ECOSYSTEM

Tick √ where necessary on the box provided.

11. What are the impacts of climate change on Kakamega Tropical Rainforest?

Responses	**SA**	**A**	**UD**	**D**	**SD**
Changes in productivity					
Functional trait composition					
Species extinction or range redistribution					
Increased fire frequency					
Changes in precipitation and warming					
Others (specify)					

SA - Strongly Agree, A- Agree, UN- Undecided, D- Disagree, SD - Strongly Disagree

SECTION F: ECOSYSTEM-BASED ADAPTATION TO CLIMATE CHANGE IN KAKAMEGA TROPICAL RAIN FOREST.

Tick √ where necessary on the box provided.

12. What is Ecosystem-Based Adaptation (EbA)?

Responses	**SA**	**A**	**UD**	**D**	**SD**
Measures which use ecosystem services to attain or support adaptation to climate change.					
Others (specify)					

SA - Strongly Agree, A- Agree, UN- Undecided, D- Disagree, SD - Strongly Disagree

13. Which are the EbA initiatives implemented in Kakamega Tropical Rainforest?

Responses	**SA**	**A**	**UD**	**D**	**SD**
Policy and behavioural changes					
Targeted management					
Conservation activities					
Restoration of highly degraded dry forest					
Reducing biodiversity loss,					
Others (specify)					

SA - Strongly Agree, A- Agree, UN- Undecided, D- Disagree, SD - Strongly Disagree

14. Do you think that the forest help to adapt or mitigate climate change?

Yes ☐

No ☐

15. If Yes, specify____

____

SECTION G: CHALLENGES AND CONSTRAINTS FACING IMPLEMENTATION OF EBA INITIATIVES IN KAKAMEGA TROPICAL RAIN FOREST

Tick √ where necessary on the box provided.

16. What are the challenges and constraints facing implementation of EbA initiatives in Kakamega Tropical Rainforest?

Responses	**SA**	**A**	**UD**	**D**	**SD**
Continued uncertainties around future climate conditions					
Higher population growth rate					
Deforestation					
Poverty					
Economic reasons like the fluctuation of markets					
Physical reasons like remoteness					
Social-political reasons					
Others (specify)					

SA - Strongly Agree, A- Agree, UN- Undecided, D- Disagree, SD - Strongly Disagree

17. What advice is your office giving the national/county government to have a lasting solution to the effects of climate change on Kakamega Tropical Rain Forest Ecosystem?

____

____

Appendix III: Krejcie and Morgan Table

N	*S*	*N*	*S*	*N*	*S*
10	10	220	140	1200	291
15	14	230	144	1300	297
20	19	240	148	1400	302
25	24	250	152	1500	306
30	28	260	155	1600	310
35	32	270	159	1700	313
40	36	280	162	1800	317
45	40	290	165	1900	320
50	44	300	169	2000	322
55	48	320	175	2200	327
60	52	340	181	2400	331
65	56	360	186	2600	335
70	59	380	191	2800	338
75	63	400	196	3000	341
80	66	420	201	3500	346
85	70	440	205	4000	351
90	73	460	210	4500	354
95	76	480	214	5000	357
100	80	500	217	6000	361
110	86	550	226	7000	364
120	92	600	234	8000	367
130	97	650	242	9000	368
140	103	700	248	10000	370
150	108	750	254	15000	375
160	113	800	260	20000	377
170	118	850	265	30000	379
180	123	900	269	40000	380
190	127	950	274	50000	381
200	132	1000	278	75000	382
210	136	1100	285	1000000	384

Note.—*N* is population size. *S* is sample size.

Source: Krejcie & Morgan, 1970

Appendix IV: Research Authorization

MOI UNIVERSITY

Telephone (254) (053) 43001-8/43620 Ext. 289
Fax (254) (0321) 43047
Telex Moivarsity 35047
Direct line: 43266

P.O. BOX 3900
EDORET
KENYA

DEPARTMENT OF GEOGRAPHY

19th July 2019

TO WHOM IT MAY CONCERN

Dear Sir/Madam,

RE: MR JOHN AYIEKO ASETA ID: 22130688
STUDENT REG: SASS/DPHIL/GEO/02/2018

This is to confirm that the above is a PhD student in the department of Geography, School of Arts and Social Science, Moi University. He has been cleared to go to the field to collect data for his Thesis. He is researching on" ***Impact of Climate Change on Forest Ecosystem in Kenya: Application of Ecosystem Based Adaptation to Climate Change in Kakamega Forest Ecosystem"***

This is therefore to request you to give any assistance that the researcher may require.

Yours Sincerely,

William K.Kiplagat,
Head and Lecturer, Geography Department
Moi University

(ISO 9001:2015 Certified Institution)

NATIONAL COMMISSION FOR SCIENCE, TECHNOLOGY AND INNOVATION

Telephone:+254-20-2213471, 2241349,3310571,2219420
Fax:+254-20-318245,318249
Email: dg@nacosti.go.ke
Website : www.nacosti.go.ke
When replying please quote

NACOSTI, Upper Kabete
Off Waiyaki Way
P.O. Box 30623-00100
NAIROBI-KENYA

Ref: No. **NACOSTI/P/19/8056/29729**

Date: **8th May, 2019**

John Ayieko Aseta
Moi University
P.O. Box 3900-30100
ELDORET.

RE: RESEARCH AUTHORIZATION

Following your application for authority to carry out research on ***"Impact of climate change on forest ecosystems in Kenya: Application of ecosystem based adaptation to climate change in Kakamega Forest Ecosystem,"*** I am pleased to inform you that you have been authorized to undertake research in **Kakamega County** for the period ending **23rd April, 2020.**

You are advised to report to **the County Commissioner and the County Director of Education, Kakamega County** before embarking on the research project.

Kindly note that, as an applicant who has been licensed under the Science, Technology and Innovation Act, 2013 to conduct research in Kenya, you shall deposit **a copy** of the final research report to the Commission within **one year** of completion. The soft copy of the same should be submitted through the Online Research Information System.

DR. STEPHEN K. KIBIRU, PhD.
FOR: DIRECTOR-GENERAL/CEO

Copy to:

The County Commissioner
Kakamega County.

The County Director of Education
Kakamega County.

THE SCIENCE, TECHNOLOGY AND INNOVATION ACT, 2013

The Grant of Research Licenses is guided by the Science, Technology and Innovation (Research Licensing) Regulations, 2014.

CONDITIONS

1. **The License is valid for the proposed research, location and specified period.**
2. **The License and any rights thereunder are non-transferable.**
3. **The Licensee shall inform the County Governor before commencement of the research.**
4. **Excavation, filming and collection of specimens are subject to further necessary clearance from relevant Government Agencies.**
5. **The License does not give authority to transfer research materials.**
6. **NACOSTI may monitor and evaluate the licensed research project.**
7. **The Licensee shall submit one hard copy and upload a soft copy of their final report within one year of completion of the research.**
8. **NACOSTI reserves the right to modify the conditions of the License including cancellation without prior notice.**

National Commission for Science, Technology and innovation
P.O. Box 30623 - 00100, Nairobi, Kenya
TEL: 020 400 7000, 0713 788787, 0735 404245
Email: dg@nacosti.go.ke, registry@nacosti.go.ke
Website: www.nacosti.go.ke

REPUBLIC OF KENYA

NACOSTI

National Commission for Science, Technology and Innovation

RESEARCH LICENSE

Serial No.A 24568

CONDITIONS: see back page

THIS IS TO CERTIFY THAT:
MR. JOHN AYIEKO ASETA
of MOI UNIVERSITY, 0-30100 ELDORET,has been permitted to conduct research in *Kakamega County*

on the topic: *IMPACT OF CLIMATE CHANGE ON FOREST ECOSYSTEMS IN KENYA: APPLICATION OF ECOSYSTEM BASED ADAPTATION TO CLIMATE CHANGE IN KAKAMEGA FOREST ECOSYSTEM*

for the period ending:
23rd April,2020

Permit No : NACOSTI/P/19/8056/29729
Date Of Issue : 8th May,2019
Fee Recieved :Ksh 2000

....
Applicant's Signature

....
Director General
National Commission for Science, Technology & Innovation

REPUBLIC OF KENYA

THE PRESIDENCY
MINISTRY OF INTERIOR & CO-ORDINATION OF NATIONAL GOVERNMENT

COUNTY COMMISSIONER
KAKAMEGA COUNTY
P O BOX 43-50100
KAKAMEGA.

Office Mobile No: 0707 085260
Email-cckakamega12@yahoo.com

When replying please quote

Ref No: ED/12/1/VOL.IV/174

Date: 10th July, 2019

JOHN AYIEKO ASETA
MOI UNIVERSITY
P O BOX 3900-30100
ELDORET

RE: RESEARCH AUTHORIZATION

Following your authorization vide letter Ref: NACOSTI/P/19/ 8056/29729 dated 8th May, 2019 by NACOSTI to undertake research on ***"Impact of climate change on forest ecosystems in Kenya: Application of ecosystem based adaptation to climate change in Kakamega Forest Ecosystem."*** I am pleased to inform you that you have been authorized to carry out the research on the same.

COUNTY COMMISSIONER
KAKAMEGA COUNTY

V. CHERONO
FOR: COUNTY COMMISSIONER
KAKAMEGA COUNTY

KENYA Forest Service

Karura, Off Kiambu Rd
P. O. Box 30513 - 00100
Nairobi, Kenya.

Ref. No. RESEA/1/KFS/Vol IV (100)

Date: 29th July 2019

John Ayieko Aseta
Moi University
P.O. Box 3900-00100
ELDORET

RE: AUTHORITY TO CARRY OUT RESEARCH IN KAKAMEGA TROPICAL RAIN FOREST

Reference is made to your undated letter to the Chief Conservator of Forests and the letter from the Department of Geography dated 19th July 2019 in which you have requested access to Kakamega Forest.

Permission is hereby granted to you to access the forest for purposes of conducting research on Climate Change.

As part of the requirement, a report must be availed to the Chief Conservator of Forests on completion of your work.

By a copy of this permit, the respective Ecosystem Conservator is hereby instructed to facilitate unhindered access.

Julius Kamau
Chief Conservator of Forests

Copy to: HoC, Western Conservancy
Ecosystem Conservator, Kakamega

Rose Akombo, CCU – KFS

MG/jb

Trees for better lives

Tel: (254) 020-3754904/5/6, (254) 020-2014663, (254)020-2020285, Fax: (254)020- 2385374
Email: info@kenyaforestservice.org, Website: www.kenyaforestservice.org

MINISTRY OF EDUCATION
STATE DEPARTMENT OF EARLY LEARNING AND BASIC EDUCATION

Telephone: 056 – 30411
Fax : 056 – 31307
E-mail : wespropde@yahoo.com
When replying please quote

COUNTY DIRECTOR OF EDUCATION
KAKAMEGA COUNTY
P. O. BOX 137 - 50100
KAKAMEGA

REF: KAK/C/GA/29/17 V/24

10th July, 2019

John Ayieko Aseta
Moi University
P. O.Box 3900 – 300100
ELDORET

RE: RESEARCH AUTHORIZATION

The above has been granted permission by National Commission for Science, Technology and Innovation vide their letter Ref: NACOSTI/P/19/8056/29729 dated 8th May, 2019, to carry out research on "**Impact of climate change on forest ecosystems in Kenya: Application of ecosystem bsed adaptation to climate change in kakamega Forest Ecosystem: Kakamega County among other Counties**", for a period ending **23rd April, 2020**

Please accord him any necessary assistance he may require.

COUNTY DIRECTOR OF EDUCATION
KAKAMEGA COUNTY

KASEMBELI DAVID
FOR: CDE/CEB – SECRETARY
KAKAMEGA COUNTY

KENYA FOREST SERVICE

KENYA
Forest Service

rphone:
en replying please quote
ail:zmkakamega@kenyaforestservice.org

ECOSYSTEM CONSERVATOR
KAKAMEGA COUNTY
P.O. BOX 1233
KAKAMEGA

: No. KFS/KC/9/1/1/199

Date: 21st June, 2019

THE STATION MANAGER
KAKAMEGA

RE: AUTHORITY TO CARRY OUT RESEARCH IN KAKAMEGA TROPICAL RAIN FOREST.

Reference is made to the Chief Conservator of Forests letter ref. no. RESEA/1/KFS/VOL.IV/100 of 29th July 2019 on the subject.

As instructed by the CCF, facilitate unhindered access of Mr John Aseta of Moi University on his research within Kakamega forest.

Attached here, please find a copy of authorization letter from CCF.

Moses Wesansa
FOR ECOSYSTEM CONSERVATOR
KAKAMEGA

CC HEAD OF CONSERVANCY (W)

Mr John Aseta