UNIVERSITY OF NAIROBI
Institute for Climate Change and Adaptation

USE OF SCIENTIFIC AND INDIGENOUS KNOWLEDGE IN ADAPTING TO CLIMATE CHANGE AND VARIABILITY AT THE KENYAN COAST

by

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I58/74436/2014

A thesis submitted in partial fulfilment for the award of the degree of

Master of Climate Change Adaptation of the University of Nairobi

August 2017

DECLARATION

I declare that this thesis is my original work and has not been submitted elsewhere for research. Where other people's work has been used, this has properly been acknowledged and referenced in accordance with the University of Nairobi's requirements.

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DEDICATION

To my son Osiemo Matundura who aroused in me the desire to pursue academic greatness; my parents Mrs. Evelyne and Mr. David Ogega, my lovely siblings Misati, Nyang'au and Bosibori, and colleagues and friends for their invaluable support.

ACKNOWLEDGEMENT

To the Almighty God from whom all good things come, I convey my profound gratitude. Today I stand testimony to the doing of God. He has seen me through the most challenging of situations, and this far that I've come, He has been Ebenezer. To Him be all the glory. My heartfelt thanks to individuals and organizations without whom this study would not have been successful. Many thanks to the wonderful faculty at the University of Nairobi's Institute for Climate Change and Adaptation (ICCA) led by Sir Shem Wandiga. It was very rewarding for me to be your student. I salute my mentors Dr. Gilbert Ouma, Ms. Eunice Boruru, Dr. Benjamin Gyampoh, Dr. Christopher Oludhe, Dr. Philip Omondi and Dr. David Obura. Your invaluable guidance throughout my research has been unparalleled. I thank you.

Special thanks to the CORDIO East Africa team led by Dr. David Obura for being kind enough to fund my fieldwork. It was a complete privilege for me to be enjoined in the WIOMSA funded MASMA project dubbed Emerging Knowledge for Local Adaptation. I'm particularly indebted to Lenice Ojwang and James Mbugua for their unmatched hospitality, guidance and assistance in my fieldwork endeavours. Many thanks to my colleagues at the Embassy of Sweden in Nairobi, and El Granero ABS. I'm particularly grateful to Mr. Protase Echessah and Jeanette Klangefeldt for pushing me off my feet when I almost backed out. And to the awesome MCCA class of year 2014, you guys are simply the best. It was a privilege for me to be your classmate, and to learn from your invaluable contributions to our learning experience. Thank you for tirelessly reading my drafts of the concept note, proposal and thesis report, and for attending my presentations and making valuable contributions.

May I also give my special thanks to my parents, Mrs. Evelyne and Mr. David Ogega for going, often, out of their means to provide us with a good education. My brothers Jaspher (Jeff) and Misati, my sister Bosibori, my friends and colleagues Dr. Joshua Ngaina (FAO), Mr. Bethwel Mutai (UON), Hussen Endris (ICPAC), Chris Tuikong (KMD), Cindy Musyoki (El Granero ABS), and Anita Iminza, and all my friends and colleagues, may God bless you.

ABSTRACT

Coastal farming communities in Kenya are already experiencing the impacts of climate change and variability. This requires urgent and sustainable adaptation strategies to build the resilience of the farming communities against the changing climate. This study sought to evaluate traditional coping strategies and propose appropriate adaptation strategies for the study area in the face of the changing climate. To this end, the study evaluated historical and projected climate trends, and how the variability and change affected coastal farming communities. It also evaluated how coastal farming communities were coping with the climate change and variability, and whether or not the existing coping strategies were effective in the face of a changing climate.

Observed climate data from the Kenya Meteorological Department were subjected to standard statistical analysis to generate the historical climate for the Kenyan coast. Future climate scenarios were developed using the Coordinated Regional climate Downscaling Experiment (CORDEX RCA) climate model outputs (driven by eight global climate models (GCM)) and used to inform the projected climate outlook over the study area. Results showed a negative but significant trend in precipitation and a positive trend for both minimum and maximum temperature in historical data. Projected climate showed a positive trend in rainfall for the period 2015 to 2045 for both the Representative Concentration Pathway (RCP) 4.5 and the RCP 8.5.

Through semi-structured questionnaires, focus group discussions and interviews, socio-economic characteristics of farming communities and ongoing coping/adaptation strategies to impacts of climate change were assessed. Results from the survey indicated that the effects of climate change on farming communities at the Kenyan coast were generally similar irrespective of the locality. Local communities employ both indigenous and modern strategies to cope with climatic change impacts with the support of the state, the county governments and non-state actors through knowledge provision. However, there was limited uptake and implementation of adaptation measures in the study area.

The study generated useful information that could inform the adoption of appropriate and sustainable climate change and variability adaptation options in the study area. Further, an integrated climate change adaptation framework that could be adopted in the study area was generated from this study. It is recommended that the local administration adopts the framework for effective climate change adaptation and enhanced local and regional socio-economic development.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF ACRONYMS/ABBREVIATIONS AND SYMBOLS

AEZs	Agro Ecological Zones
AR5	Assessment Report Five
CCCma	Canadian Centre for Climate Modelling and Analysis
CDO	Climate Data Operators
CERFACS	Centre Européen de Recherche et Formation Avancées en Calcul Scientifique
CIDP	County Integrated Development Plan
CMA	Coast Development Authority
CNRM	Centre National de Recherches Météorologiques
CORDEX	Coordinated Regional climate Downscaling Experiment
CRU TS	Climate Research Unit Time Series
CSA	Climate Smart Agriculture
EC-EARTH	An Earth System Model
ECMWF	European Centre for Medium-Range Weather Forecasts
ENSmean	Ensemble Mean (average of all models used in the study)
ERA	ECMWF re-analysis
FGD	Focus Group Discussion
GCM	Global Climate Model
GFDL	Geophysical Fluid Dynamics Laboratory
GHG	Green House Gas
IPCC	Intergovernmental Panel on Climate Change
JJA	June, July and August
KACCAL	Kenya Adaptation to Climate Change in Arid and semi-arid Lands
KAPPAP	A meeting hall in Kwale Town
KCNRN	Kwale County Natural Resources Network
KMD	Kenya Meteorological Department
KYCN	Kenya Youth Climate Network
M$E	Monitoring and Evaluation
MAM	March, April and May
MIROC	Model for Interdisciplinary Research on Climate
MOHC	Met Office Hadley Centre
MPI-M	Max Planck Institute for Meteorology

NCC	Norwegian Climate Centre
NDMA	National Drought Management Authority
NOAA	National Oceanic and Atmospheric Agency
OND	October, November and December
Open GrADS	Open Grid Analysis and Display System
RCA	Rossby Centre regional atmospheric model
RCM	Regional Climate Models
RCP	Representative Concentration Pathway
SMHI	Sveriges Meteorologiska och Hydrologiska Institut
SPSS	Statistical Package for the Social Sciences
SRES	Special Report on Emission Scenarios
UN	United Nations
USDA	United States Department of Agriculture
WCRP	World Climate Research Programme
WMO	World Meteorological Organization

CHAPTER ONE

1 INTRODUCTION

1.1 Background of the study

Warming of the global climate structure is now undeniable and rainfall patterns, just like other parameters, will be impacted by the ensuing climate change and variability (IPCC, 2014). Given the limitation of the current computer technology, global climate models (GCMs) have not been able to make a seamless representation of surface heterogeneities on scales of less than 100 Km (Jacob *et al.*, 2007). Yet, these regional and local levels (that the current computer technology is not able to sufficiently capture) are significantly influenced by global climate systems.

The limitation of GCMs to make a seamless representation at regional and local scales is addressed by Regional Climate Models (RCMs) which downscale GCM outputs to scales useful for simulating local climate (Jacob *et al.* 2007). For instance, the equatorial Eastern Africa region is one of the most complex climatic areas of the African continent (Nicholson and Entekhabi 1986). Large-scale tropical systems, including major convergence zones, are superimposed on regional factors such as topography, lakes and maritime influence (Nicholson and Entekhabi 1986). RCMs provide useful information in understanding the climate of complex regions such as Eastern Africa.

In its fifth assessment report (AR5), the Intergovernmental Panel on Climate Change (IPCC) adopted the use of Representative Concentration Pathways (RCP) in place of the emission scenarios (SRES). There are four pathways; RCP 2.6, RCP 4.5, RCP 6.0 and RCP 8.5. The pathways imply the possible extent of radiative forcing values (+2.6, +4.5, +6.0, and +8.5 W/m^2, respectively) by the year 2100 as a result of anthropogenic activities (IPCC, 2014a). The World Climate Research Program runs a program referred to as the coordinated regional climate downscaling experiment (CORDEX). CORDEX makes it possible to generate high-resolution climate projections at regional and local scales (Giorgi *et al.*, 2009) based on the RCPs.

Climate change and variability affect various environmental resources including biodiversity, wildlife and water resources. Its effects hamper sustainable livelihoods and the socio-economic development; particularly so for rural areas in developing countries (Dasgupta *et al.*, 2014). There is, therefore, need for an interdisciplinary approach in unfolding the complexity of climate change and its impacts on ecosystems and their goods and services (Scott *et al.*, 2005).

The Kenyan coast is rich with various resources including mangroves and other coastal forests, marine species, coral reefs and marine resources of the open sea. These assets support livelihoods and socio-economic development at the Kenyan coast and the region as a whole. Further, the resources maintain the health and function of coastal and marine ecosystems (Ongoma and Onyango, 2014). Consequently, the formulation and implementation of robust and sustainable planning, design and administration of risk-based usage of water and other resources is paramount (Onyutha and Willems, 2014).

1.2 Scope of the research work

This subsection highlights the theme, relevance, problem statement, research questions and limitations of the study.

1.2.1 Main theme of the research work

The main theme of this research was to investigate future climate change and variability (seasonal, annual and inter-annual variability) over the Kenyan coast and its impacts on the socio-economic development of the region. Rain-fed agriculture is one of the main economic activities in East Africa (WFP, 2015) in general and at the Kenyan coast in particular. Therefore, any changes in climate are likely to affect agricultural production and, eventually, the livelihoods and the economy of the region. Anecdotal information suggests that agriculture and livelihoods of coastal smallholder communities in Kenya are already experiencing the impacts of climate change. This highlights the need to revitalize existing agricultural systems to enable them stand and survive the impacts of a changing climate.

1.2.2 Relevance of the main theme to science and development

Food security and sustainable livelihoods of the most vulnerable populations whose livelihoods are climate-dependent are at stake. The findings of this study shall contribute to the prerequisite knowledge needed to address the impacts of climate change.

1.2.3 Problem statement

While significant progress has been made towards understanding the drivers of mean rainfall and temperature characteristics in climate model projections, changes in regional tropical rainfall under anthropogenic forcing remain one of the least certain areas of current climate projections (Douville *et al.*, 2005; Xie *et al.*, 2015; He and Soden, 2016). Conversely, regional climate variability (especially rainfall and temperature) have potential significant impacts on food and water security, agriculture, tourism and biodiversity (Nicholls *et al.*, 2007) in the region.

The effects of climate change and variability were being experienced at the Kenyan coast, just like many other parts of the country, where smallholder rain-fed crop farming was the primary source of livelihood. Knowledge of appropriate adaptation strategies in the face of a changing climate was scanty and unavailable in many cases (Mombasa County Government, 2013; Kilifi County, 2013; and County Government of Kwale, 2013). The little available climate knowledge is often inadequate in addressing the current needs of the region. This study sought to identify knowledge gaps and blend existing indigenous knowledge with scientific knowledge to generate information that could inspire effective climate change adaptation over the Kenyan coast.

1.2.4 Limitation of the study

Observational weather data were obtained from the Kenya Meteorological Department (KMD). However, some weather stations in Kwale County did not have sufficient data for climatology analysis. For that reason, blended data from GeoCLIM was used to analyse the climatology of that area. In achieving the second and third objectives the study, some semi-structured questionnaire interviews were done via telephone. This was necessitated by the fact that some parts of the study area are far-flung and posed a logistical and security challenge to access them. As a result, the information given over telephone may not have, always, been an accurate representation of the picture on the ground. Random sampling of respondents and validation of responses using focus group discussions (FGDs) ensured that the responses obtained from the social survey were consistent.

1.3 Research questions

The following research questions guided this research:

1. What are the historical climate trends and future climate projections over the Kenyan coast?
2. How have these changes affect coastal smallholder farmers?
3. How are the coastal communities in Kenya coping with the impacts of climate change and variability?
4. Are the existing coping strategies useful in the face of a changing climate?

1.4 Objectives of the study

The overall objective of this study was to investigate how a blend of scientific and indigenous climate knowledge could be used to inform effective climate change adaptation for coastal communities in Kenya.

The specific objectives were:

1. To determine historical climate trends over the Kenyan coast
2. To generate future climate change and variability projections using CORDEX RCMs
3. To evaluate indigenous and historical coping strategies and their effectiveness in responding to a changing climate.
4. To propose appropriate climate change adaptation measures for coastal smallholder farmers in the Kenya

1.5 Justification of the study

All the three county governments in the study area highlighted the unavailability of adequate meteorological and climate information in their jurisdictions. Yet, these counties were already faced by the impacts of climate change and variability. Kilifi County, for instance, faced prolonged droughts than usual while parts of Kwale County, such as Vanga, experienced more flood episodes than normal. The changing trends, in terms of intensity, frequency and duration, called for decisive action to enable communities in the study area face and survive from the impacts of the changing climate.

This study sought to generate climate information that could inform identification, design, and implementation of appropriate and sustainable climate change adaptation measures over the Kenyan coast. This information would inspire decision makers to formulate climate-sensitive policies that would enhance the resilience of communities against a changing climate.

The choice of the Kenyan coast, as a study area, was informed by the fact that the area was already experiencing a myriad of internal and external shocks. These shocks included perennial land ownership problems, prevailing abject poverty conditions and low literacy levels. Any additional shocks, such as the impacts of climate change and variability, could cripple an already struggling community. The research topic was designed to encompass the ideology of trans-disciplinarity for a holistic approach to solving the problem under study.

1.6 Conceptual framework

A conceptual framework can be defined as an interlinked set of ideas about how parts of a given phenomenon are related. The framework gives a basis of understanding the correlational or causal patterns of inter-linkages across ideas, events, observations, knowledge, concepts and other elements of experience (Svinicki, 2010).

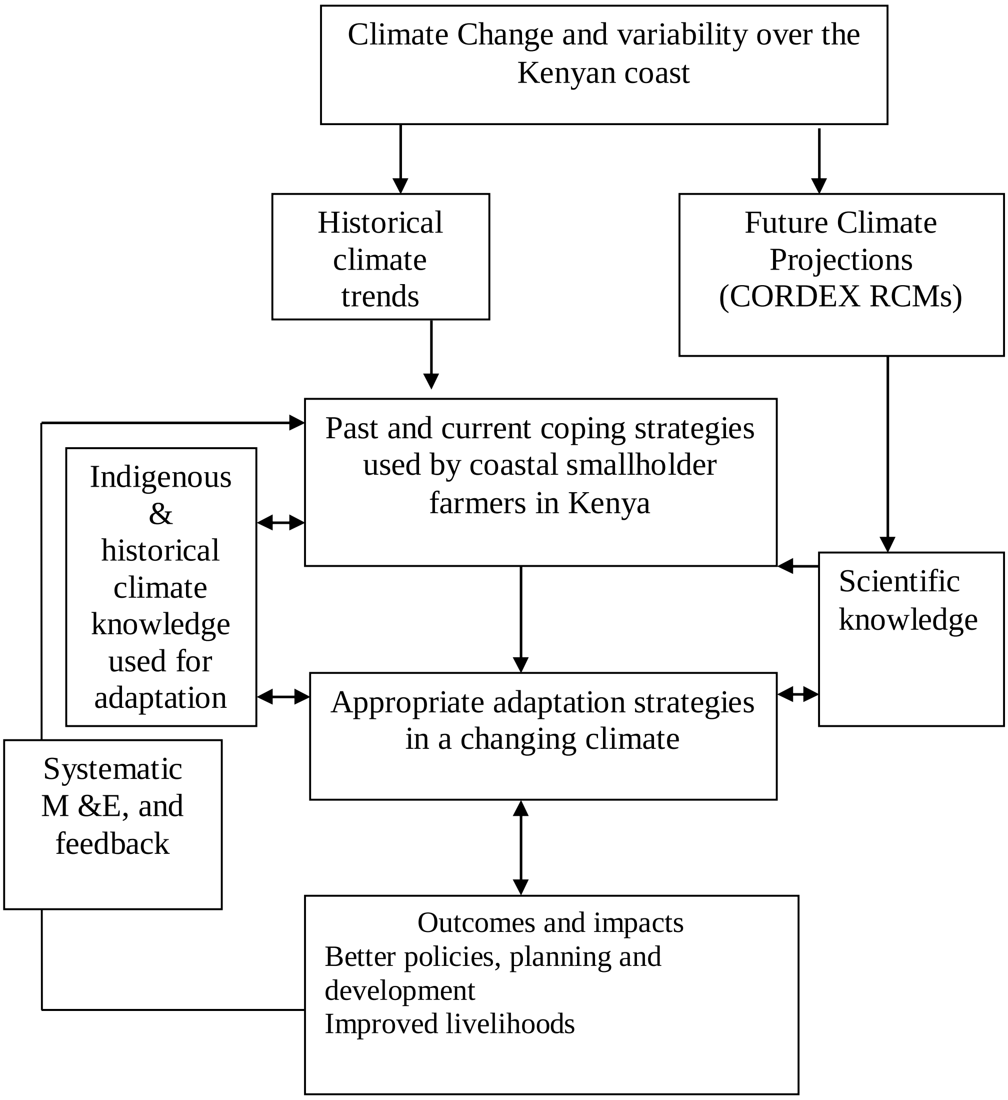

Figure 1: A conceptual framework used for this study.

As illustrated in Figure 1, climate change and variability over the Kenyan coast being the problem, historical climate data was analysed to give past climate trends for the area of study. A social survey (semi-structured questionnaire interviews and focus group discussions (FGDs)) identify indigenous and historical knowledge used by coastal communities to respond to a changing climate. CORDEX RCM data output was used to generate future climate projections for the study area. A blend of indigenous knowledge and scientific knowledge is used to formulate appropriate climate change adaptation measures for the area of study.

1.7 Study area

This section gives background details of the study area.

1.7.1 Location and description

The study covered the Kenyan coast in general but focused on Kwale, Mombasa, and Kilifi counties. Figure 2 is a map of Kenya showing the location of the study area.

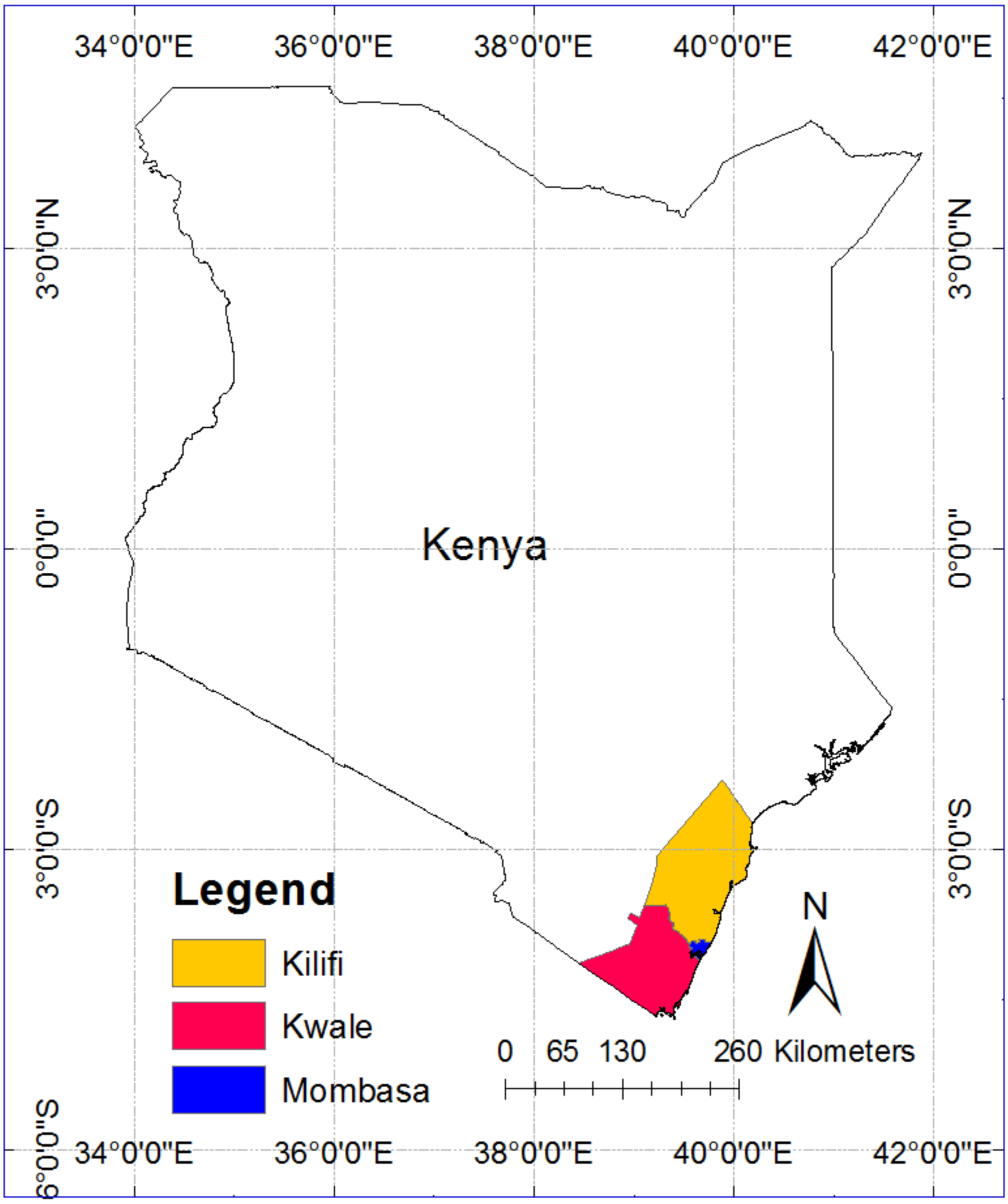

Figure 2: Location of Kwale, Mombasa and Kilifi counties

1.7.2 Kwale County

Kwale is one of the six counties in Kenya's coastal region; with an estimated population of 713,488 people (346,931 males and 366,589 females). As shown in Figure 2, Kwale County is located between latitudes 3.05^{o} and 4.75^{o} south and longitudes 38.52^{o} and 39.52^{o} East (County Government of Kwale, 2013). The Coastal Plain, the Coastal Uplands, the Foot Plateau and the Nyika Plateau are the major topographic features of Kwale County. Regarding agricultural potential, 67 percent of the county is rangeland, arid and semi-arid land. Fifteen percent of the land has medium potential while the remaining 18 percent is marginal land. The County's annual precipitation averages below 800mm (County Government of Kwale, 2013).

Table 1: Kwale County's Agro-Ecological Zones (Source: County Government of Kwale, 2013)

#	Agro-ecological zones	Characteristics	Economic activities
1	Lowland Sugarcane Zone, L2	Long to medium cropping season and intermediate rains	Generally, a high potential area. Some of the farming activities include production of grain, tubers, oil crops and vegetables. Others include cultivating tropical fruits, coconuts, rice, sugarcane, cashew nuts, and pasture and forage for animals.
2	Coconut, Cassava Zone, L3	Good to fair yield potential (20 - 40 per cent of the optimum)	This zone is also suitable for grain, tubers, pulses, tropical fruits, oil crops, vegetables and Coconuts
3	Cashew nut-Cassava Zone, L 4	Intermediate rains	The zone is marked by high potential for production of cashew nuts, cassava and sisal; and medium potential for grain, pulses, tubers, oil crops, and pasture and forage.
4	Lowland Livestock Millet Zone, L5	It is a poor-to-fair potential zone. Small leaved bush land is predominant.	Suitable for sorghum, millet, green grams, and cassava. Livestock rearing is predominant activity
5	Lowland Ranching Zone, L6	Has bimodal rainfall. Short grass mixed with small leaved bush land is predominant.	Livestock rearing (cattle, sheep and goats)

Kwale County has a monsoon type of climate. January to around May is usually hot, while June to August experiences coolest temperatures in the year. The mean annual rainfall at the coastal belt is 1000mm with a significant decrease in intensity hinterland and to the north. Average temperatures range from 26.3^{o}C to 26.6^{o}C at the coastal belt, 25^{o}C to 26.6^{o}C at Shimba Hills, and 24.6^{o}C to 27.5^{o}C hinterland (County Government of Kwale, 2013).

1.7.3 Mombasa County

Mombasa County lies between latitudes 3.93º and 4.17º South and longitudes 39.57º and 39.77º East. The county experiences monsoon winds with the long rains season (April to June) averaging at 1040mmand the short rains season (October to December) averages at 240 mm. The average annual rainfall in Mombasa County is 640 mm while the mean annual temperature is 27.9ºC (Mombasa County Government, 2013).

Mombasa County is characterized as an urban area. It is clustered into the following zones: industrial; low, medium and high density residential areas; sub-urban; central business district; peri-urban and informal settlements (Mombasa County Government, 2013). The county has 400 ha under food crop production and 500 ha under cash crop production. Some of the crops grown include cassava, maize, millet, sorghum, and vegetables (Mombasa County Government, 2013).

1.7.4 Kilifi County

Lying between latitude 2.33º and 4.0ºsouth, and between longitude 39.08º and 40.23º East, Kilifi County is one of the six counties at the Kenyan coast. The county is divided into Agro-Ecological Zones (AEZs) which include Coconut-Cassava Zone, Cashew nut – Cassava Zone, Livestock-Millet Zone, Lowland Ranching and Coconut Cashew nut-Cassava Zone (Kilifi County, 2013). Kilifi has a mean annual rainfall ranging from 300mm at the hinterland to about 1300mm at the coastal strip. The March to May (MAM) season is the wettest season for Kilifi, followed by the October to December (OND) season. The county receives intermittent rainfall in the June July August (JJA) season. The county has the highest evaporation rate between January and March. Temperatures range from 21ºC to 30ºC at the coastal belt and from 30ºC and 34ºC at the hinterland (Kilifi County, 2013).

Some of the environmental changes in Kilifi County that could be attributed to a changing climate included increased severity and frequency of extreme weather events such as the frequent flooding in Magarini Constituency (Kilifi County, 2013). Fluctuating onset and cessation rainfall dates is also rampant in the county. Floods in some parts of Kilifi have impacted on various sectors including the health sector which has seen the occurrence of diseases such as diarrhoea and malaria (Kilifi County, 2013).

CHAPTER TWO

2 LITERATURE REVIEW

2.1 Introduction

This section gives a broad review of the literature including theories around the use of scientific and indigenous knowledge in adapting to climate change and variability. However, the review focused on four main themes that emerge from the literature. These themes are climate trends; impacts of climate change; vulnerability of coastal communities to climate change and current coping strategies; and adaptation to climate change and variability at the Kenyan coast. This review highlights the themes' relationship and application to climate change adaptation.

Climate change and variability information play a critical role in guiding water management related applications (Onyutha and Willems, 2014). Rainfall projections in the East African region (under RCP 8.5) predict an increase of up to 40 percent while temperature is expected to reach approximately 4.5^{o} C by 2100 (IPCC, 2014). Some of the drivers of climate change in Kenya include a change in vegetative cover and an increase greenhouse gas (GHG) emissions.

2.1.1 Definition of key terms

Climate change refers to any identifiable (using statistical tests, etc.) changes in the state of climate over a given area and a given period, typically decades or longer (IPCC, 2007).

Climate change adaptation refers to adjustments in human or natural systems made in response to actual or expected climatic hazards or their effects, which minimizes harm or takes advantage of beneficial opportunities (IPCC, 2007). Coping strategies refer to actions taken by people to face immediate consequences. Coping takes place during the occurrence of a calamity (UN/ISDR, 2004).

Vulnerability to climate change refers to the extent to which a system is prone to, and unable to cope with, adverse effects of climate change, including climate variability and extremes. Vulnerability is a function of the magnitude, character, and rate of climate change and variation to which a system is exposed, the sensitivity and adaptive capacity of that system (Adger, 2006; IPCC, 2007).

2.2 Causes of climate change

Climate change is caused by both naturally occurring events and human activities. The human activities cause changes in the earth's atmosphere by altering the quantities of greenhouse gases, cloudiness and aerosols (IPCC, 2007a). Aerosols and greenhouse gases alter the earth's incoming solar radiation and outgoing infrared radiation hence changing the earth's energy balance (IPCC, 2007a). As a result, the earth's climate system experiences cooling or warming.

Since the pre-industrial period, economic and population growth have contributed to increased anthropogenic greenhouse gas emissions into the atmosphere. The greenhouse gases with unprecedented concentrations in the atmosphere include methane, carbon dioxide, and nitrous oxide. The effects of these greenhouse gases are extremely likely to be the principal cause of the warming that the global climate system has experienced since the mid-20th century (IPCC, 2014).

The climate is sensitive to changes in vegetation (Kutzback *et al.*, 1996; Cao *et al.*, 2015; Yan *et al.*, 2017). However, the sensitivity and the extent of sensitivity of the climate vary from one region to the other (Chase *et al.*, 2000). Changes in vegetative cover affect the climate in two ways: modification of the land surface characteristics and the alteration of greenhouse gas composition in the atmosphere (Brovkin, 2002). A change in physical land features such as surface albedo and roughness affect the amount of short-wave radiation from the sun that is reflected into space, and that is absorbed in the atmosphere; hence changing the cooling or warming of a given area.

Yet, the extent of anthropogenic contributions to climate change remains uncertain (Hegerl *et al.* 2007; IPCC, 2014). This calls for continued research to enhance the understanding of contributions of human activities to climate change for better climate prediction and projection.

2.3 Climate trends

This section discusses current and future climate trends locally and globally.

2.3.1 Trends in global climate

The period 2001- 2010 was the warmest decade ever recorded since the beginning of modern weather measurements around 1850 (WMO, 2013). The decade recorded above-mean precipitation with year 2010 recording the highest rainfall ever. The decade also saw an occurrence of extreme weather events such as the 2010 floods in Pakistan, the 2003 European heat-wave and the prolonged droughts in Australia, Amazon Basin and East Africa (WMO, 2013).

According to WMO (2014), the global mean temperature for the year 2014 was 0.57 ± 0.09°C above the 1961-1990 global average of 14°C. Year 2014 was also 0.08°C above the 0.50°C mean temperature anomaly for the period 2005 – 2014; nominally placing 2014 as the warmest year on record (WMO, 2014). Regarding precipitation, the global average was near the long-term average of 1033 mm. However, some areas experienced lower and higher than average rainfall (WMO, 2014).

The year 2015 showed a continued increase in global average temperatures. For instance, the combined mean temperature (over the global ocean and land surfaces) for October 2015 was 0.98°C; the highest for the month of October for the past 136 years (NOAA, 2015). This increase in temperature was the sixth consecutive month where a monthly global temperature record had been broken. It was also the biggest departure from the mean for any given month in the past 1630 months of recordkeeping – breaking the previous record high departure from the average, which had been set just in September 2015, by 0.07°C (NOAA, 2015).

2.3.2 Trends in local climate

Rainfall in East Africa has shown significant downward trends especially in the rainfall totals for the March, April and May (MAM) season (Lyon and DeWitt, 2012; Viste *et al.*, 2013 and Liebmann *et al.*, 2014). Monsoonal precipitation declined in many parts of the Great Horn of Africa (GHA) during the 1948-2009 period due to changing sea level pressure gradient between Sudan and the southern coast of the Mediterranean Sea and the southern tropical Indian Ocean region (Williams *et al*., 2012).

The October to December (OND) season rainfall totals have remained fairly constant but with large inter-annual variability (Hastenrath *et al.*, 2011). There is a general agreement that the ensuing decline in rainfall trends is due to the evolving characteristics of anomalous sea surface temperatures (SSTs) (Ogallo *et al.*, 1988; Camberlin and Philippon, 2002). Williams and Funk (2011) link the Indian Ocean's influence on East Africa's rainfall while El Niño Southern Oscillation (ENSO) patterns (particularly La Niña) play a prime role in East Africa's rainfall patterns (Lyon, 2014; Yang *et al.*, 2014).

Rowell *et al.*, (2015) note insufficiency of detailed analysis of rainfall projections in East Africa. There is need to investigate the recent SST trends with a particular focus on whether they have been derived from anthropogenic forcing or from natural climate system variability.

2.3.3 Future global climate projections

The IPCC's fourth assessment report (AR4) did an extensive analysis on the global climate projections. All models assessed indicated increased global mean surface air temperature; largely due to increased anthropogenic greenhouse gas emissions into the atmosphere (Meehl *et al.*, 2007). Heat waves are very likely to occur more frequently and for longer periods. Extreme precipitation events are projected to be more frequent and intense in many regions. Warming and acidification of the ocean will continue, and the global mean sea level will rise (Meehl *et al.*, 2007).

2.3.4 Future climate projections over the study area

Projections from the Coupled Model Inter-comparison Project phase 5 (CMIP5) indicate likely increases in mean annual precipitation over central and eastern Africa, for RCP 8.5, from the mid-21st century (Taylor *et al.*, 2012). Most of the mid-latitude land masses as well as over the wet tropical regions are very likely to experience extreme precipitation events with more intensity and frequency (Shongwe *et al.*, 2011; IPCC, 2014). This increasing rainfall is attributed to recent cooling in the eastern equatorial Pacific that cancels out the equatorial Pacific SST warming that is projected by the Coupled Model Inter-comparison Project phase 3 (CMIP3) Global Climate models (GCMs) (Lyon and DeWitt, 2012). The precipitation is likely to be characterized by variability over space and time. The variability is likely to be dominated by various physical processes (Hession and Moore, 2011) including the rapid warming of the Indian Ocean which has been attributed to a decrease in rainfall during the MAM season (Williams and Funk, 2011).

Regional climate model assessments indicate a drying climate over most parts of east Africa during the months of August and September by end of the 21stcentury due to a weakening Indian monsoon and Somali jet (Patricola and Cook, 2011). Truncated boreal spring rains by mid-21st century have been indicated over Somalia, eastern Ethiopia, Tanzania, and southern Kenya (Cook and Vizy, 2013). The boreal fall season is said to increase in length over Tanzania and southern parts of Kenya (Nakaegawa *et al.*, 2012).

Extreme precipitation changes over East Africa, including droughts and heavy rainfall, have been recorded more frequently in the last 60 years or so (Williams and Funk, 2011; Lyon and DeWitt, 2012). More frequent droughts in East Africa during the summer and winter seasons have been linked to a continued warming in the Indian-Pacific warm during the last 30 years (Williams and Funk, 2011). However, it is not clear whether the changes in precipitation are due to multi-decadal natural variability or anthropogenic influences (Lyon *et al*., 2013). Rainfall projections indicate increasing trends over the region with high certainty (Seneviratne *et al*., 2012).

During the 21st century, temperature in Africa is projected to increase faster than the global average (Joshi *et al*., 2011; James and Washington, 2013). Maximum and minimum temperature projections over equatorial eastern Africa indicate a significant rise in the number of days with warmer temperature, by mid and end of the 21st century, than the 2°C 1981-2000 average (Anyah and Qiu, 2012).

2.4 Impacts of climate change

Climate change impacts on patterns of settlement, incomes and livelihoods in rural areas (Dasgupta *et al.*, 2014). These impacts will emanate from extreme events including floods, droughts, storms, heat waves and generally higher temperatures which are likely to affect rural infrastructure (Kirshen *et al*., 2008) and potentially cause loss of life. The impacts will affect agriculture and other ecosystems (including fisheries, rangelands and wildlife areas) on which communities in rural areas depend (Dasgupta *et al*., 2014). Due to the high dependence of rural areas on natural resources, rural communities are likely to be seriously impacted by the changing climate (Dasgupta *et al*., 2014). The consequences of climate change would include rural-urban migration (Afifi, 2011; Gray and Mueller, 2012) hence collapsing rural systems that depend on the rural communities' human capital. However, the changing climate may trigger interventions aimed at building the rural communities' adaptive capacity. Such interventions are, for instance, likely to increase employment opportunities for the rural communities (del Rio and Burguillo, 2008), landscape changes resulting from the supply and use of renewable energy solutions (Prados, 2010). Conflicts over scarce resources at the community level (such as water) may also occur (Blair *et al.*, 2011).

In the tropics, smallholder farmers are particularly susceptible to potential temperature-induced reduction in crop yields, and increasing severity and frequency of drought (Morton, 2007). These impacts of climate change and variability often lead to enhanced potential of crop failure; increased occurrence of diseases and mortality of livestock; impacts on livelihood including dependency on food relief; potential feedbacks via unsustainable adaptation interventions often resulting into environmental degradation; and gradual impacts on human development indicators including education and health (Morton, 2007).

The Kenyan coast has a history of various extreme climate events, such as floods, which have been causing havoc almost on a yearly basis (UN-Habitat, 2008). The coast also has low-lying areas which are susceptible to flooding, saltwater intrusion towards land as well as shoreline erosion (Okemwa *et al.*, 1997).

2.5 Use of indigenous knowledge in climate change adaptation

Indigenous knowledge refers to knowledge systems that have been developed by a community as opposed to scientific knowledge which is referred to as modern knowledge (Ajibade, 2003). In many rural communities, the indigenous knowledge, often, informs local-level decision-making. Blending indigenous knowledge with scientific knowledge in climate change policy formulation and implementation can potentially lead to cost-effective, sustainable and participatory adaptation strategies (Robinson and Herbert, 2001). However, incorporating indigenous knowledge into scientific knowledge based climate change adaptation has various challenges. First, the nature of observations done by both scientists and indigenous observers may be different (Nichols *et al.*, 2004). Indigenous observers tend to combine multiple environmental and social factors in making their forecasts while scientists often single out a single environmental variable to make their inferences (Weatherhead *et al.*, 2010; Marin, 2010). Nevertheless, continued research efforts should be made to improve the understanding of indigenous knowledge systems and their potential contribution in climate change adaptation efforts.

2.6 Vulnerability of coastal communities to climate change

Poverty is one of the factors that render communities vulnerable to climate change and variability (Olago *et al.*, 2007). The prevailing abject poverty conditions at the Kenyan coast make it difficult for coastal communities to have effective mechanisms for coping with the impacts of climate change (including extreme weather events and disease).

Kebede *et al.* (2010) remarked that appropriate adaptation and mitigation strategies ought to be put in place to keep the risks, to which Mombasa and the entire Kenyan coast are exposed, at acceptable levels. A changing climate, coupled with increasing mean and severe sea level, aggravates the risks to which the Kenyan coast is exposed. Exposure of a given community to external shocks diminishes household assets; plunging the said households into poverty (Muyanga *et al.*, 2013). Given that coastal communities in Kenya are already suffering from multiple stressors (such as disease and abject poverty conditions) any additional shocks on these communities are likely to impact significantly on the communities' socio-economic well-being.

Institutional policy frameworks help in building capacity for intervention in case of an occurrence of extreme weather events. According to Agrawal (2008), adaptation to climate change is, unavoidably, local. Institutions influence local adaptation by structuring impacts and vulnerability. They also mediate between collective and individual responses to the effects of climate change hence shaping the outcomes of adaptation. Further, institutions act as a means of delivering external resources in the facilitation of adjustments and, thus, governing access to such remedies (Agrawal, 2008).

2.7 Coping and adaptation to climate change and variability at the Kenyan coast

Climate has been found to be the primary determining factor of productivity in agriculture (Adams *et al.*, 1998). Environmental aspects, including moisture and temperature, affect plant systems (hence crop yields) by either antagonistically or synergistically determining crop yields (Waggoner, 1983).

Kandlinkar and Risbey (2000) deduced that adaptation happens at both the farm level and at the macro-level. The farm-level involves decisions that farmers make in relation to their farming practices. The macro level deals with issues to do with agricultural production at the national level but in tandem with existing domestic and international policy. On one hand, farm-level decisions are short-lived and often made as a response to climatic variability. The decisions are, often, influenced by socio-economic variables including household resources, family features, and access to information on agriculture (Ibid). Macro-level decisions, on the other hand, involve long-term strategies and interventions at the national level against changes (long-term) in the market and climatic conditions.

CHAPTER THREE

3 MATERIALS AND METHODS

This section provides information on various methods and materials that were used towards the achievement of the set study objectives. The section is grouped into the following subsections; data, the methodology of the study and limitations of the study.

3.1 Data

This subsection provides information on sources of data, methods used in checking data homogeneity, and data analysis techniques that were used in achieving the objectives of the study.

3.1.1 Desktop studies

Literature on historical climate change and variability in East Africa and the Kenyan coast was reviewed. Information on future climate projections from global climate models (GCMs) and regional climate models (RCMs) was collected. This information informed the determination of climate trends in the study area.

The County Integrated Development Plans (CIDPs) for Kwale, Mombasa and Kilifi counties provided valuable information on the status of the counties under study. This information was an essential ingredient in proposing appropriate adaptation strategies that the counties in the study area ought to embrace to effectively adapt to a changing climate.

3.1.2 Observed climate data

Monthly rainfall (for the period 1957 to 2013) and temperature data (for the period 1961 to 2012) for Mtwapa, Msabaha and Malindi weather stations in Kilifi County, and Mombasa Station in Mombasa County were obtained from the Kenya Meteorological Department (KMD). Rainfall data from GeoCLIM tools (Yannick *et al.*, 2004a; Goddéris *et al.*, 2005) for the period 1981 to 2013 were used to analyse historical climate trends in Kwale County; given that Kwale had no KMD weather station with adequate past climate data. The data from KMD and GeoCLIM were used to achieve the first objective of the study.

Both the Single Mass Curve method and Bartlett's test were used to check the consistency of the observed data. Preference was given to the Shortcut Bartlett method because of its robustness and ease of use in assessing the consistency of data.

3.1.3 CORDEX RCM data

CORDEX RCMs make it possible to generate high-resolution regional climate projections (Giorgi *et al.*, 2009). In its fifth assessment report (AR5), the Intergovernmental Panel on Climate Change (IPCC) adopted the use of Representative Concentration Pathways (RCPs) in place of the emission scenarios (SRES). There are four pathways; RCP 2.6, RCP 4.5, RCP 6.0 and RCP 8.5. The pathways imply the possible extent of radiative forcing values (+2.6, +4.5, +6.0, and +8.5 W/m^2, respectively) by the year 2100 following anthropogenic activities (IPCC, 2014a).

Given that previous research (such as Endris *et al.*, 2013) had assessed the suitability of RCMs to simulate climate in East Africa, this study found it imperative to choose one RCM from the CORDEX RCMs that have been investigated before (Endris *et al.*, 2013). An existing CORDEX RCM namely the Regional Atmospheric Model (RCA3.5; Samuelsson *et al.*, (2010); hereafter RCA) from the Sveriges Meteorologiska och Hydrologiska Institut (SMHI) Rossby Centre in Sweden was used in this study. The RCA, driven by 8 Global Climate Models (GCM), simulates the exchange between the atmosphere and the land surface (SMHI, 2007). Climate index calculations are made with a horizontal resolution of approximately 50 km (SMHI, 2007).

Gridded precipitation and temperature data obtained from the Climatic Research Unit time series (CRU TS) were used to compare the performance of the RCA data output and the observed climate (Mitchell and Jones, 2005). The Climatic Research Unit (CRU) of the University of East Anglia in the UK studies natural and anthropogenic climate change. CRU TS series of datasets contains monthly time series of some variables (such precipitation and temperature) that cover Earth’s land areas for the period 1901-2012. The data set is gridded to 0.5^o by 0.5^o resolution (NCAR, 2015). This study used CRU TS data to evaluate how well the CORDEX RCA models could simulate climate over the Kenyan coast. Given that GCMs are only forced by lateral conditions, the European Centre for Medium-Range Weather Forecasts (ECMWF) Interim Re-Analysis (ERA-Interim) was used for comparison. The ERA-Interim data is obtained by forcing RCMs by both lateral and surface boundary conditions.

Table 2: List of GCMs driving the CORDEX RCA (adopted from Taylor *et al.*, 2012).

Institute Name	GCM name	INSTITUTION
CCCma (Canada)	CanESM2	Canadian Centre for Climate Modelling and Analysis
MPI-M (Germany)	MPI-ESM-LR	Max Planck Institute for Meteorology (MPI-M)
ICHEC (Europe)	EC-EARTH	EC-EARTH Consortium
CNRM-CERFACS (France)	CNRM-CM5	Centre National de Recherches Météorologiques/Centre Européen de Recherche et Formation Avancées en Calcul Scientifique
MIROC (Japan)	MIROC5	Atmosphere and Ocean Research Institute (The University of Tokyo), National Institute for Environmental Studies, and Japan Agency for Marine-Earth Science and Technology
MOHC (UK)	HadGEM2-ES	Met Office Hadley Centre (additional HadGEM2-ES realizations contributed by Instituto Nacional de Pesquisas Espaciais)
NCC (Norway)	NorESM1-M	Norwegian Climate Centre
NOAA-GFDL (USA)	GFDL-ESM2M	Geophysical Fluid Dynamics Laboratory

Table 2 shows a list and brief description of the GCMs that drive the RCA model that was used in this study. A detailed description of the models is given in Taylor *et al.* (2012).

3.1.4 Fieldwork

Towards the realization of objectives 3 and 4, a social survey was conducted in the study area. Given that climatic conditions at the Kenyan coast are relatively homogenous, semi-structured questionnaire (Appendix ii) interviews were done on smallholder farmers in Kilifi County. The findings of the interviews were validated with follow-up focus group discussions (FGDs) (Appendix i).

According to Eliot and Associates (2005), an FGD should be comprised of six to ten participants led through an open discussion by a trained moderator. FGDs are structured around carefully predetermined questions, but with a free-flowing discussion. An FGD should have a maximum of twelve questions with eight questions considered to be ideal (Eliot and Associates, 2005; Berkowitz, 2015).

The semi-structured questionnaires were designed to generate information on whether a changing climate had informed past coping strategies in the study area or not. The FGDs highlighted relevant indigenous knowledge that could be merged with scientific knowledge to propose appropriate climate change adaptation strategies as detailed in subsections3.2.4and 4.4.

The sample size for the semi-structured questionnaire interviews was estimated using the predetermined margin of error (UNC, 2010).

$$\boldsymbol{ME} = \boldsymbol{z}\sqrt{\frac{\boldsymbol{p(1-p)}}{\boldsymbol{n}}};$$ .... Equation 1

(Where *n* is the sample size to be determined, and *z* is the z-score (in this case 1.96; corresponding to 95 percent confidence level). *P* is the percentage of households assumed (based on general knowledge, etc.) to be at risk of the impacts of climate change (in this case, 60 percent of the population given that smallholder farming in the county was predominantly rain-fed), and *ME* is the desired degree of accuracy of *p* (in this case 0.025).

Using Equation 1, the sample size was calculated to be 1,500 people in the study area. Given that farming in the study area is, mostly, done at a household level, each respondent was assumed to be responding on behalf of his/her entire household. The average household size for Kilifi County is six persons (Kilifi County, 2013). This implied that a minimum of 250 questionnaires would be administered.

The study picked 274 respondents from the semi-structured questionnaire interviews. The respondents were randomly selected from all the seven sub-counties of Kilifi County. Some of the interviews were done via telephone while others were done on one-on-one basis. The results of the questionnaire interviews were then analysed using SPSS and MS Excel software and the results recorded in subsection 4.3. The findings of the questionnaire interviews were shared with the community and other stakeholders through the FGDs. The outcomes of the FGDs were recorded in subsection 4.4.1.

3.2 Methodology

This subsection provides details of the methods that were used in achieving the objectives of the study.

3.2.1 Determining historical trends in climate

This subsection was divided into temporal time series analysis and spatial time series analysis. For temporal analysis, a seasonal time series analysis (for the period 1971 to 2010) for the observational rainfall data over Mombasa and Kilifi counties was done.

In East Africa, the MAM season is largely driven by regional and local factors such as the Inter-Tropical Convergence Zone (ITCZ). The OND season, on the other hand, is driven by large-scale factors such as the sea-surface temperature variability that are closely linked to the atmospheric general circulation (Davies *et al.*, 1985; Minja, 1985; Anyamba and Ogallo, 1985; and Nicholson and Entekhabi, 1986). The study considered the March to May (MAM) and October to December (OND) seasons for Mtwapa and Malindi stations in Kilifi County, and Mombasa station in Mombasa County. The choice of the MAM and the OND seasons was informed by the fact that they are the planting seasons at the Kenyan coast. Due to Kwale County's lack of weather stations with sufficient climatological data, blended rainfall data were obtained from GeoCLIM tools. The results of the temporal analysis were recorded in subsection 4.1.

Spatial data were displayed by the Open Grid Analysis and Display System (Open GrADS). Open GrADS is an interactive desktop tool that is used for easy access, manipulation and visualization of earth science data (Open GrADS, 2014). The software is designed to handle gridded datasets, but it can also process station data. Masking of spatial plots with shape files was done using the ArcGIS software.

3.2.1.1 Bartlett's test

The Bartlett's test is a method used to check the homogeneity of a working series of data (Mitchell, 1966). In other words, Bartlett's test is used to check if *k* samples of a working series are from populations that have equal variances. Many statistical techniques work on the assumption of equal variance. However, simple group comparisons (such as means) can be misleading – if the variability within the groups is not homogenous (Shanks and Hutton, 1986). Bartlett's test makes it possible to check whether the variance in various classes or groups of data is constant or not. The working series is divided into k equal parts of n values each (provided that $k \geq 2$).

In tests of significance, one expects alternative hypothesis to be true if the null hypothesis is false. It is impossible to prove that the alternative hypothesis is true, but one can demonstrate that the alternative hypothesis is better than the null hypothesis given the data. This demonstration is, usually, expressed in terms of probability (a *P*-value) that quantifies the strength of the evidence provided for the alternative hypothesis, but against the null (Hooper, n.d.). In this case, the *P*-value is a measure of proof. In a more formal way, the *P*-value can be reported in terms of a fixed level α test. Here, α is a number chosen independently of the data (usually 0.05 or 0.01). One rejects the null hypothesis, at level α, if the *P*-value is smaller than α. Otherwise, the null hypothesis is not rejected (Hooper, n.d.).

The working series in this study (1961 to 2010) was divided into five groups of eight yearly totals for Mtwapa, Mombasa, Msabaha and Malindi stations. The Bartlett's test was, then, run in the R software, and the results recorded in subsection 4.1.1.

3.2.1.2 Single Mass Curve

A double mass curve is used to check the homogeneity of a given dataset. It is a plot of the cumulative values of a given variable against the aggregate values of another variable for the same period (Searcy and Hardison, 1960). The plot of the cumulative values of a single variable against a given period (at a single station) is referred to as a single mass-curve. The theory of a double mass curve is based on the fact that a graph plotted for the cumulative values of one variable against the aggregate values of another, for the same period, will have a straight line provided that the data used is proportional. In such a case, the gradient of the line plotted will be a representation of the constant of proportionality between the two variables.

A break in the in the slope of the double mass curve implies a variation in the constant of proportionality, or that the proportionality between the two variables is inconsistent throughout the accumulation (Searcy and Hardison, 1960). For this study, a single mass-curve for precipitation was plotted and the results recorded in subsection 5.1.1.1.

3.2.1.3 Trend analysis for observed climate data

The Mann-Kendall rank statistic was used to check the significance of the trend of the time series, while the linear slope of the trend was estimated using the Sen's slope method (Gilbert, 1987). The Mann-Kendall rank statistic has been said to be the most appropriate tool for analysing climatic changes. The test can detect the climatic discontinuity in a climatological time series (Chrysoulakis *et al.*, 2002). The ranks y^i of all terms x^i in a series when arranged in an ascending order of magnitude are used in the test. For each of the elements y^i, the number n^i of its preceding element ($i>j$) is computed such that $y^i>y^j$. The test statistic is given in equation 2.

$t_{i=\sum_i n_i}$ ....Equation 2.0

Further, the distribution function of the statistic under the null hypothesis is said to be asymptotically normal with mean and variance given by Equation 2.1 and Equation 2.2, respectively.

$E(t_i) = n(n\text{-}1)/4$ ....Equation 2.1

$Var(t_i) = \frac{n(n-1)(25+5)}{72}$ ....Equation 2.2

In case of large values of $u(t_i)$;

$u(t_i) = \frac{[n(t_i)-E(t_i)]}{\sqrt{Var(t_i)}}$ ....Equation 2.3

Under these conditions, a probability α_1, is determined from the standard normal distribution table such that;

$\alpha_1 = P(|u| > |u(t_i)|)\frac{[n(t_i)-E(t_i)]}{\sqrt{Var(t_i)}}$ ....Equation 2.4

Accepting or rejecting the null hypothesis at α level is based on whether $\alpha_{1>}\alpha_0$ or$\alpha_{1<}\alpha_{0.}$ If the absolute values of $u\ (t_i\ )$ are higher than 1.96, then there is a decreasing or increasing trend. The presence of a significant trend ($\alpha \geq 0.05$) in a time series implies that the beginning of the trend is located through sequential analysis (Chrysoulakis *et al.*, 2002; and Ngaina, 2016). Severally overlapping curves indicate an absence of a trend. This study considered 0.05 to be the significance level (α).

The presence of a statistically significant trend in a time series is evaluated using the Z value. If the absolute value of Z is greater than $Z_{1\alpha/2}$ (where $Z_{\alpha/2}$ is obtained from the standard normal cumulative distribution tables) then the null hypothesis (H_o) is rejected implying that the trend is significant, and vice versa (Motiee and McBean, 2009). A negative value of Z indicates a decreasing trend (of a two-tailed test) while a positive value of Z indicates an upward trend

(Salmi et al., 2002). A Microsoft Excel template application – Mann-Kendall rank statistic for trend and Sen's Slope estimates (MAKESENS) combines both the Mann-Kendall rank statistic method and the Sen's estimation method. The MAKESENS template was developed by the Finnish Meteorological Institute (Salmi *et al.*, 2002) for trend detection and estimation for annual values. The results of the Mann-Kendall rank statistic are discussed in subsection 4.1.2.1.

3.2.2 Future climate projections

This study focused on the RCP 4.5 (business as usual scenario) and RCP 8.5 (worst case scenario). The period 1971 to 2000 was used as a baseline, and the model data output was compared to blended data from CRU, for the same period 1971 to 2000. This was done to assess how well the models could simulate climate over the Kenyan coast.

Rainfall timeseries of spatially averaged seasonal temperature and rainfall anomalies were analysed for the study area. The analysis was aimed at predicting future seasonal climatology, annual rainfall cycles and inter-annual climate variability. The MAM, and the OND seasons were considered.

3.2.2.1 Climatology

The study established the baseline for climatology to be the period 1971 to 2000. The Climate Data Operators (CDO) software was used to calculate the climatological sum over all time steps. The period 1971 to 2000 was selected, then seasonal totals for each year calculated and summed for the entire period. The resulting files were then displayed using Open GrADS and the results recorded in subsection 4.2.1.

3.2.2.2 Annual variability

The CDO software was used to calculate the annual variability of both precipitation and temperature (minimum and maximum temperature). First, the study area was selected from the data files. Then, a field average was calculated for the selected area to get a representative figure for the study area. Next, the yearly monthly mean for the period 1971 to 2000 was then calculated. The resulting files were, then, displayed using the Open GrADS as shown in subsection 4.2.2.

3.2.2.3 Climate projections

Based on the baseline files created in subsection3.2.2.1, future climate changes over the study area were calculated for the period 2015 to 2045 for both RCP4.5 and 8.5. Yearly seasonal totals were summed up for the period 2015 to 2045. The files created for the period 2015 to 2045 were subtracted from the baseline files to calculate changes projected changes in climate. The resulting data, showing changes in seasonal precipitation (surplus or deficit), were plotted using Open GrADS. The results were recorded in subsection4.2.3.1.

3.2.3 Evaluating indigenous and historical coping strategies

This objective was carried out with the participation of the community and other stakeholders (including the County Governments). An initial field visit was done to scope. After elaborate planning, a second field visit was done to do data collection. Various stakeholders (such as Kilifi County's Department of Agriculture) were involved in identifying farmers that were sampled in this study. Other interested parties involved were the National Drought Management Authority (Kilifi branch), and the Kenya Adaptation to Climate Change in Arid and semi-arid Lands (KACCAL). Through the officers working for these organizations in all the Wards of Kilifi County, and the one-on-one contact made with the farmers, a database of eligible respondents was made.

About ten farmers were randomly selected from each of the 35 Wards of Kilifi County (totalling to about 350 respondents). To be sampled, respondents had to be practicing farmers for more than 20 years. Only one respondent per household was tested either in person or by telephone. The results of the questionnaire administration are discussed in section 4.3.

3.2.4 Proposing appropriate adaptation measures

The first FGD was conducted on 20th January 2016 at the Coast Development Authority (CMA) hall, Kilifi town, Kilifi County. The participants comprised of three farmers randomly picked from Kilifi County, one village elder, and two officials from Kilifi County Government. The FGD also had one official from KACCAL, one from the National Drought Management Authority (NDMA), and another from Kilifi County Disaster Management team.

The presence of farmers in the FGD was aimed at bringing real experiences from the field. A village elder brought the local leadership perspective while the County officials brought in the aspect of policy formulation and management. NDMA, KACCAL, and the County Disaster Management team represented technical departments that provided technical expertise in policy development and implementation at the County.

The second FGD was conducted on 21st January 2016 at KAPPAP Hall, Kwale town, Kwale County. Two farmers, a journalist from Radio RANET in Kwale, an officer from the County Meteorological office, a representative from the Kenya Youth Climate Network (KYCN) and another from Kwale County Natural Resources Network (KCNRN) formed the FGD. Here, farmers brought in farming experiences in the field. The journalist, specializing in issues around weather and climate in respect to farming, represented information disseminators. The officer from the Meteorological office represented government institutions charged with the responsibility of information generation, synthesis, and dissemination. The representative from KYCN brought in the perspective of civil society activists, while the representative from KCNRN represented the County Government. Given that Mombasa County is curved out of Kwale and Kilifi counties, the findings from both Kwale and Kilifi counties were assumed to represent the situation in Mombasa County. Further, Mombasa County is, largely, a town with little farming activities. The findings of the FGDs were compiled into a report that would be shared with stakeholders for consumption (Appendix iii). The report is discussed in subsection 4.4.1

CHAPTER FOUR

4 RESULTS AND DISCUSSION

This section gives the results that were generated from the study. The results are then discussed to put the results into perspective in line with the objectives of the study. Each study objective was discussed in its sub-section for clarity and ease of reference.

4.1 Historical trends in climate change and variability

This subsection provides information on the steps taken to achieve objective 1 of the study. The sub-section looks at data homogeneity, time-series analysis and trend analysis.

4.1.1 Data homogeneity

The homogeneity of the observed rainfall data (for the period 1971 to 2010) were checked using both Bartlett's test and the single mass-curve for all the stations. The results were recorded in Figure 3. The five colours show groups (*k*) of the data whose consistency was being checked.

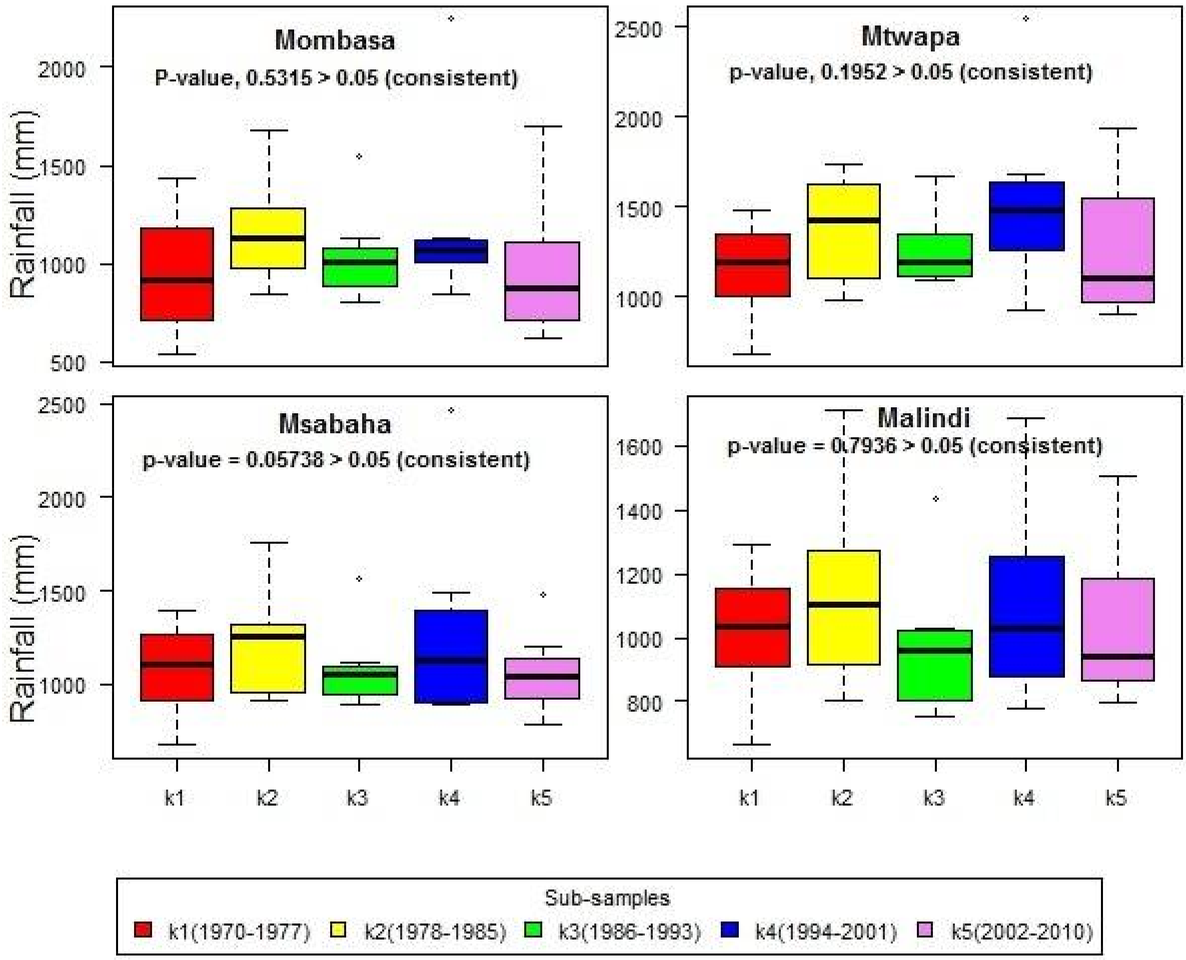

Figure 3: Homogeneity test for observed rainfall data using the Bartlett's test.

The data for all the stations (Mtwapa, Mombasa, Msabaha, and Malindi) had *p*-values greater than 0.05. As detailed in subsection 3.2.1.1, this implied that the null hypothesis (that the data is consistent) could not be rejected in favour of the alternative hypothesis (that the data were inconsistent).

To complement the Bartlett's test, single mass-curves were done for all the weather stations considered for this study. Figure 4 shows a single mass curve analysis for Malindi station in Kilifi County. The results were similar for other stations considered in this study. In conclusion, the observed climate data that was used in this study was homogenous.

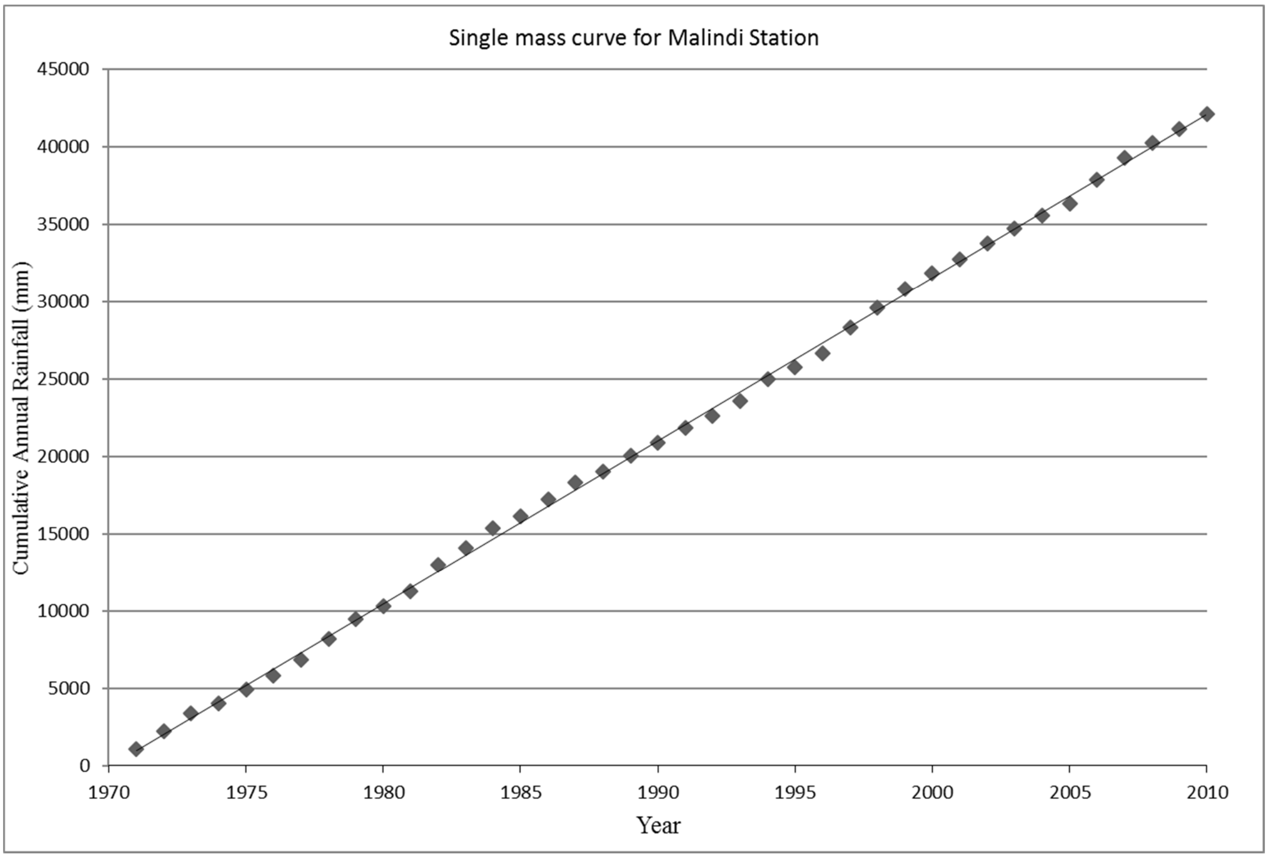

Figure 4: A single mass-curve for Malindi weather station.

4.1.2 Time series analysis

Figure 5 shows a seasonal time series for the Malindi weather station.

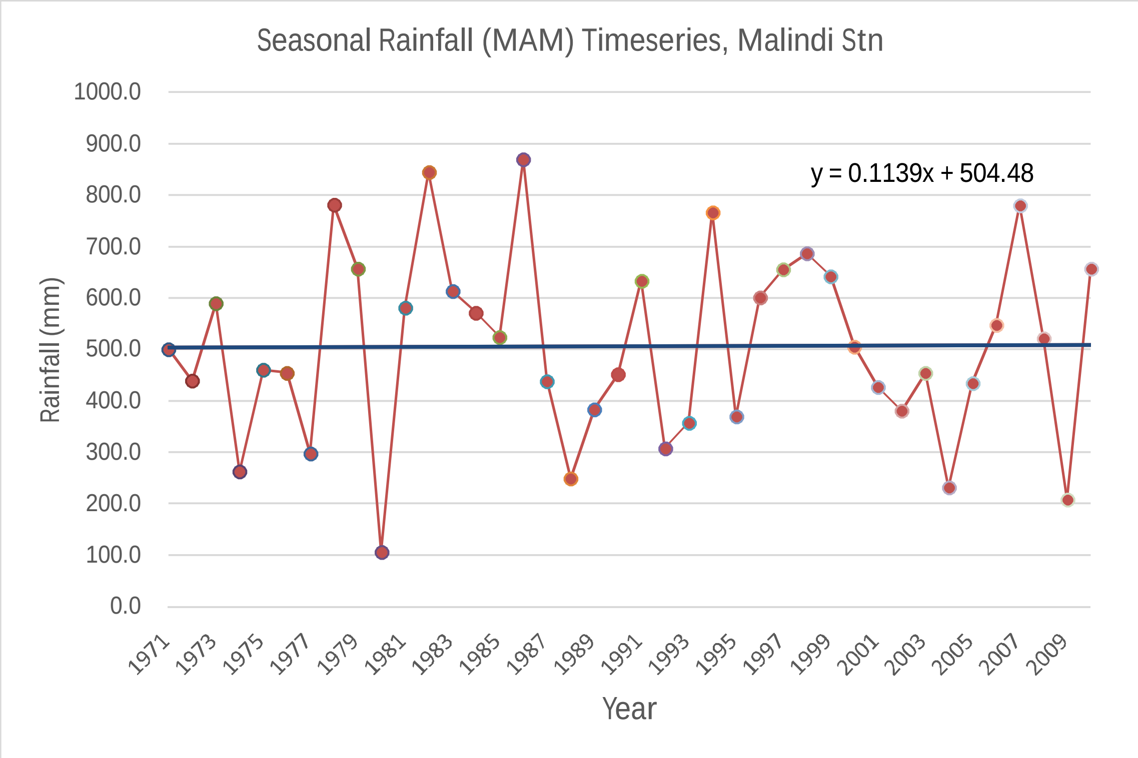

Figure 5: Seasonal time series for Malindi weather station

As shown in Figure 5, the MAM season for Malindi had no trend. Kwale County did not have sufficient recorded climatology data. For this reason, data from GeoCLIM was used to analyse past climate.

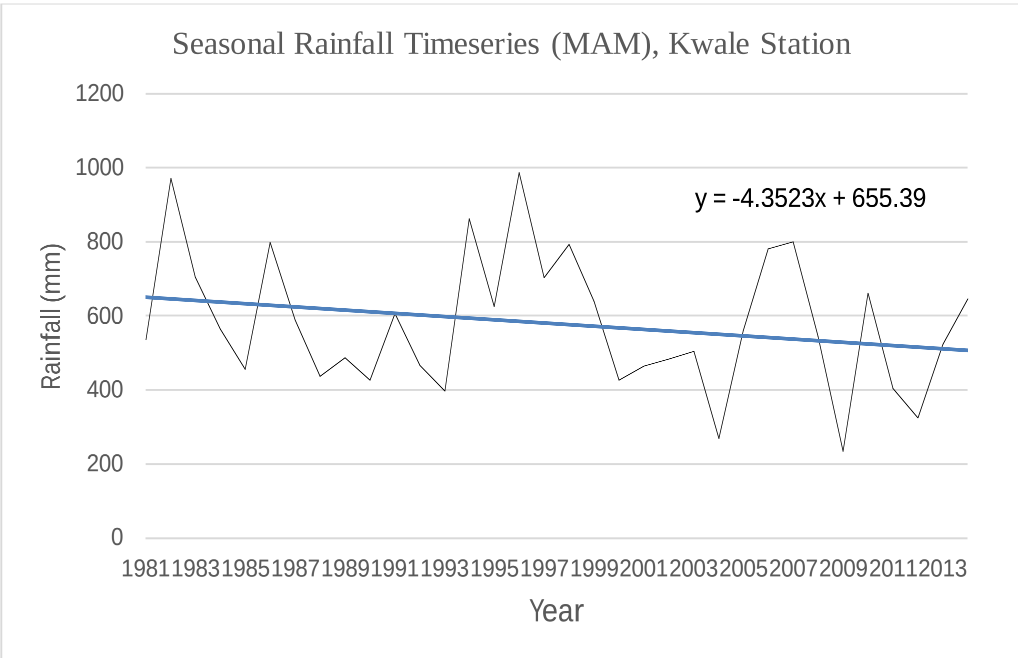

Figure 6: Seasonal (MAM) timeseries for Kwale County

Figure 6 Kwale had a decreasing trend for the MAM and JJA seasons while the OND season remained relatively constant. In addition to precipitation, trends for minimum and maximum temperatures were analysed in Kilifi and Mombasa counties. Figure 7 and Figure 8show seasonal time series for temperature in Malindi weather station, Kilifi County.

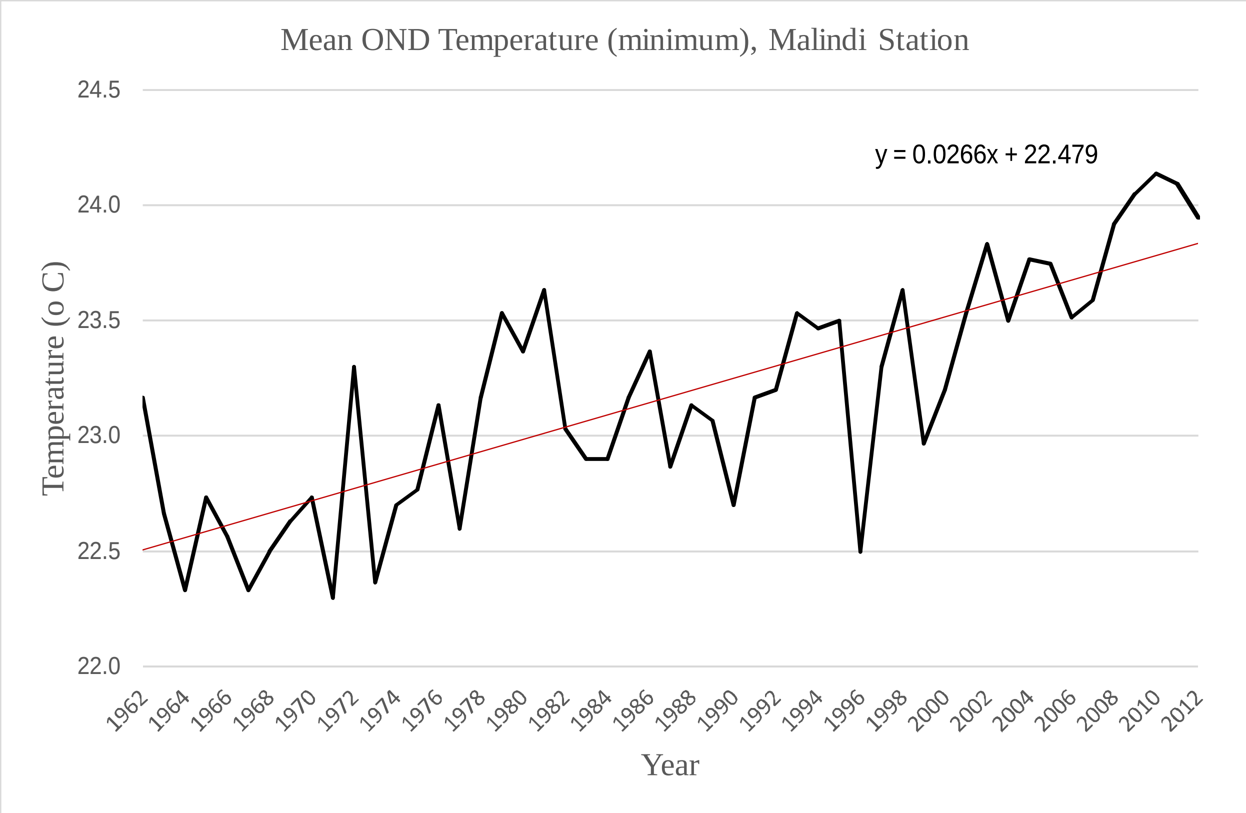

Figure 7: Average OND Minimum Temperature (Tmin) for Malindi station

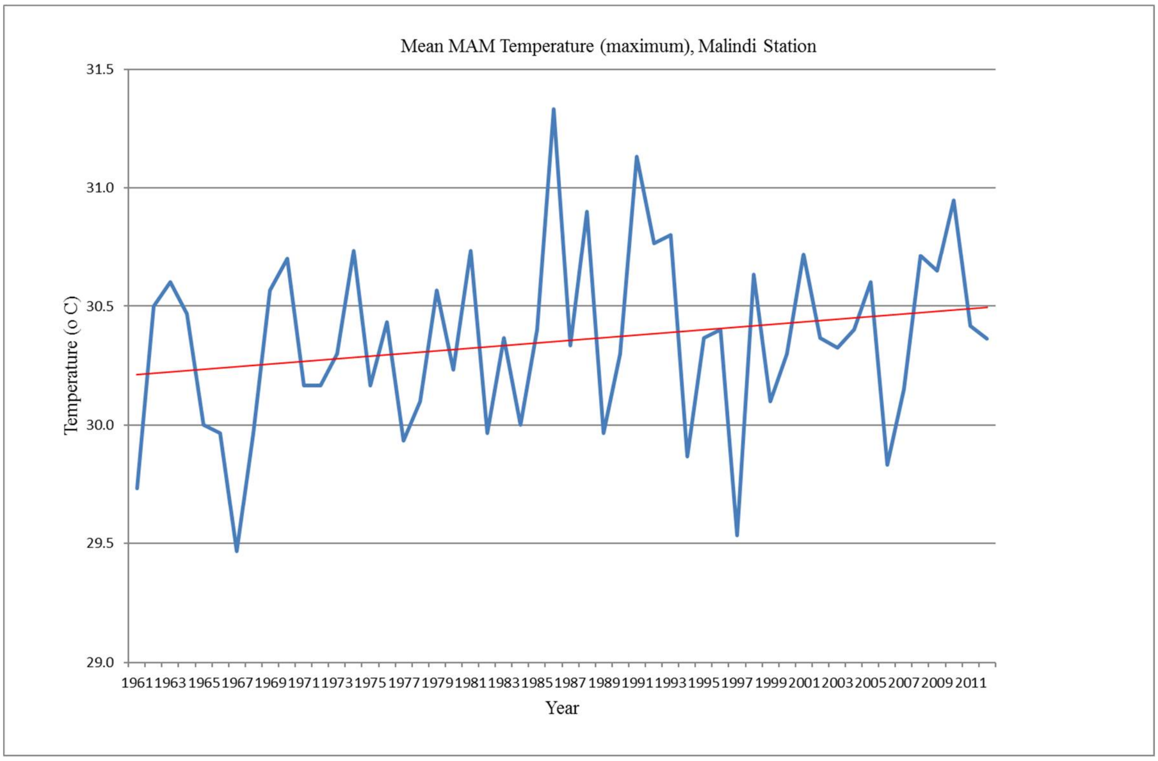

Figure 8: Average MAM Maximum Temperature (Tmax) for Malindi station

From Figure 7 and Figure 8, both minimum and maximum temperatures for Malindi station showed an increase in temperature for the period 1961 to 2012. The minimum temperature had increased from around 22.5^{o} C in 1963 to about 23.8^{o} C in 2012. The maximum temperature had increased from 30.2^{o} C in 1962 to about 30.5^{o} C in 2012. Trends for stations in the entire study area were similar to those for the Malindi station.

4.1.2.1 Trend analysis

Figure 9 presents the trend analysis of rainfall over Kwale, Mombasa and Kilifi counties. The trends were determined using the Mann-Kendall rank statistic as explained in subsection 3.2.1.3.

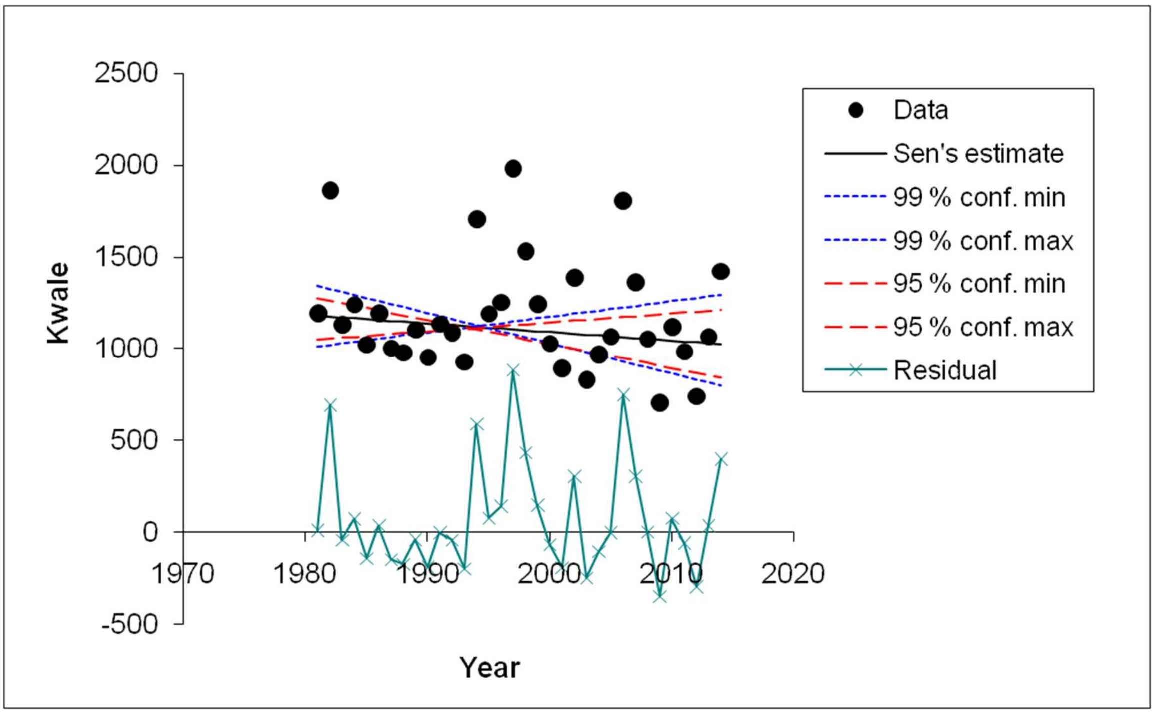

Figure 9: Trend analysis using the Mann-Kendall rank statistic and the Sen's estimate.

As depicted in Figure 9, the premises of the statistical methods that were used (Mann-Kendall rank statistic and the Sen's estimate) were fulfilled. The time series produced from the annual totals for Kwale, for instance, had decreasing trends, and the calculated residuals (data minus trend) seemed to be from a random distribution – an indication that one could apply a linear model. Table 3 gives a summary of the Mann-Kendall test Statistic calculations. The statistical calculations gave a high-level significance with a, fairly, narrow-angle between the confidence lines. Other stations considered in this study showed similar results.

Table 3: Mann-Kendall test statistic *Z* values

#	Station name	County	MAM	JJA	OND	Annual totals
1	Mombasa	Mombasa	-0.15	-0.62	0.29	-0.45
2	Mtwapa	Kilifi (at the border between Mombasa and Kilifi)	0.29	-0.87	1.27	0.50
3	Malindi	Kilifi	-0.06	-0.87	1.19	-0.45
4	Msabaha	Kilifi	0.14	-1.22	0.97	-0.24
5	Kwale	Kwale	0.50	-0.71	-0.46	-0.75

As detailed in subsection 3.2.1.3, computed *p*-values greater than alpha (0.05) imply an absence of a significant trend while calculated *p*-values less than alpha (0.05) imply the presence of a significant trend. Table 3 gives a summary of the Mann-Kendall test calculations. The results for OND season show that all the stations – except Kwale - had positive *Z* values; implying an increasing rainfall, and reducing rainfall for Kwale. The absolute values of *Z* were greater than 0.025 ($Z_{1\alpha/2}$) implying that H_o could not be accepted and, hence, that there was a significant trend for all the stations.

The MAM season indicates positive *Z* values for Mtwapa, Msabaha and Kwale stations; and negative *Z* values for Mombasa and Malindi stations. The absolute *Z* values for all the stations are greater than $Z_{1\alpha/2}$ hence implying the presence of a significant trend. The JJA season shows that all the stations had negative values of *Z* implying a reducing trend in rainfall. However, all the absolute *Z* values were greater than $Z_{1\alpha/2}$ hence implying the presence of a significant trend.

Results for annual rainfall totals indicate that Mtwapa recorded a positive value while Mombasa, Msabaha, Malindi and Kwale stations recorded negative values of *Z*. This implies that annual rainfall declined in all the stations except Mtwapa. The absolute values of *Z* were greater than $Z_{1\alpha/2}$ implying the presence of a statistically significant trend. These findings are consistent with findings from similar research that has been done before (such as Omondi *et al*. 2013; Alexander *et al*. 2006; and Caesar *et al*. 2010).

4.2 Future climate change and variability

This section looks at climate projections for the study area based on the 1970 to 2000 period baseline. Model data were compared with observed climate data to evaluate how well the models can simulate climate. The section looks at historical climatology, annual cycles, and projected climate.

4.2.1 Determining a baseline for future climate projections

The RCA model, driven by eight global models (GCMs) could capture the climatology of the study area – as shown in Figure 10 and Figure 11. Data from CRU was used to compare with the results from the RCA model. The RCA model could simulate the climate closest to the observed when driven by MPI, ICHEC and MOHC models (for both OND and MAM seasons). Hence, MPI, ICHEC and MOHC models were selected for use in generating future climate projections for the study area.

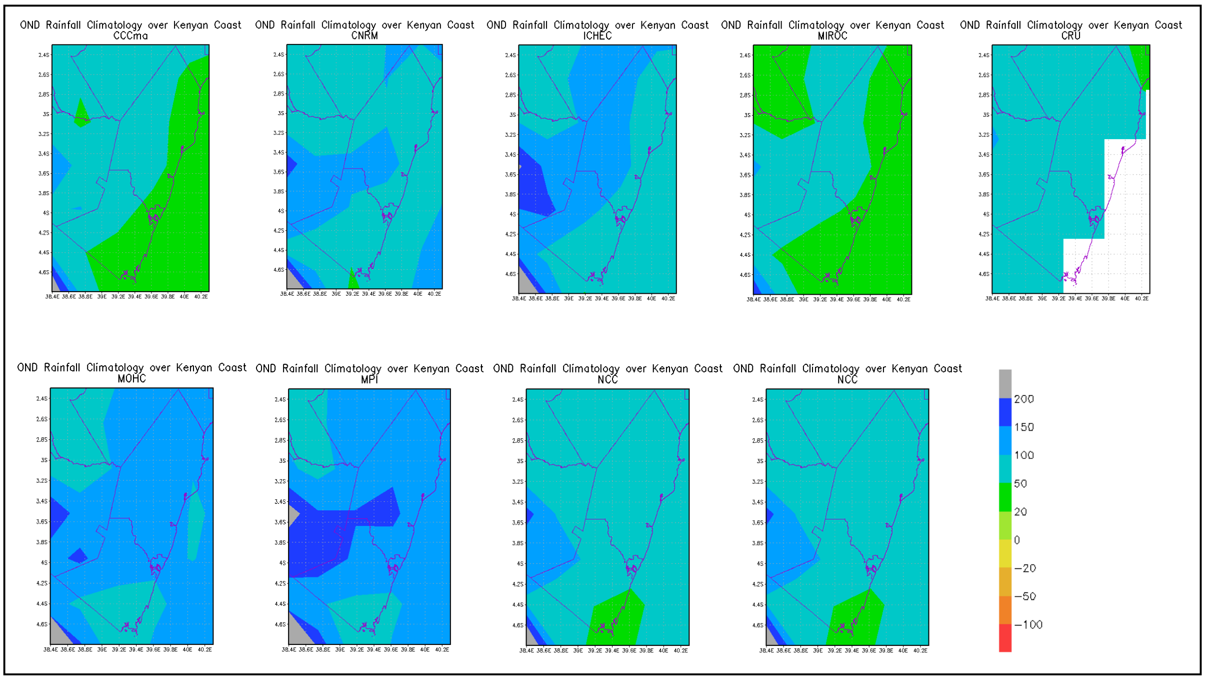

Figure 10: Seasonal climatology (OND rainfall) as simulated by the RCA model

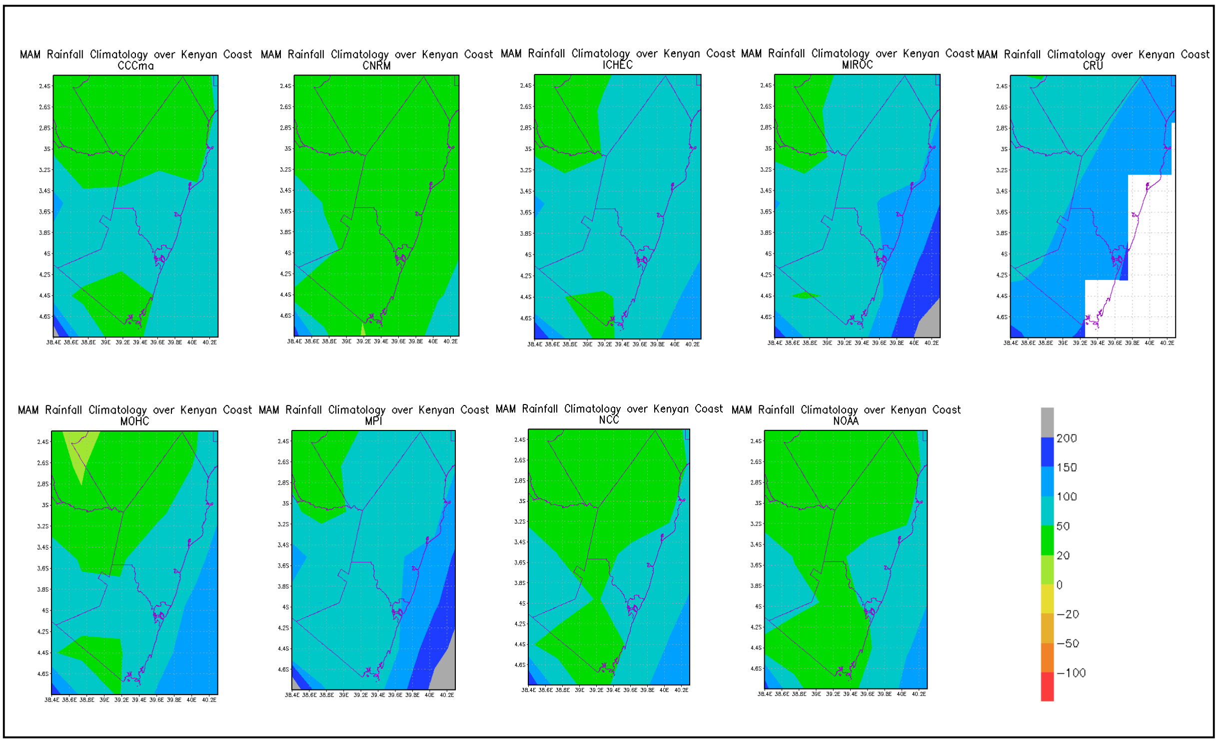

Figure 11: Seasonal climatology (OND rainfall) as simulated by the RCA model

4.2.2 Annual cycles

Figure 12, Figure 13, and Figure 14 represent the annual cycles of precipitation, maximum temperature (Tmax) and minimum temperature (Tmin), respectively. The figures show a representation the simulation done by the RCA model, driven by 8 GCMs, in comparison to CRU and ERAINT data.

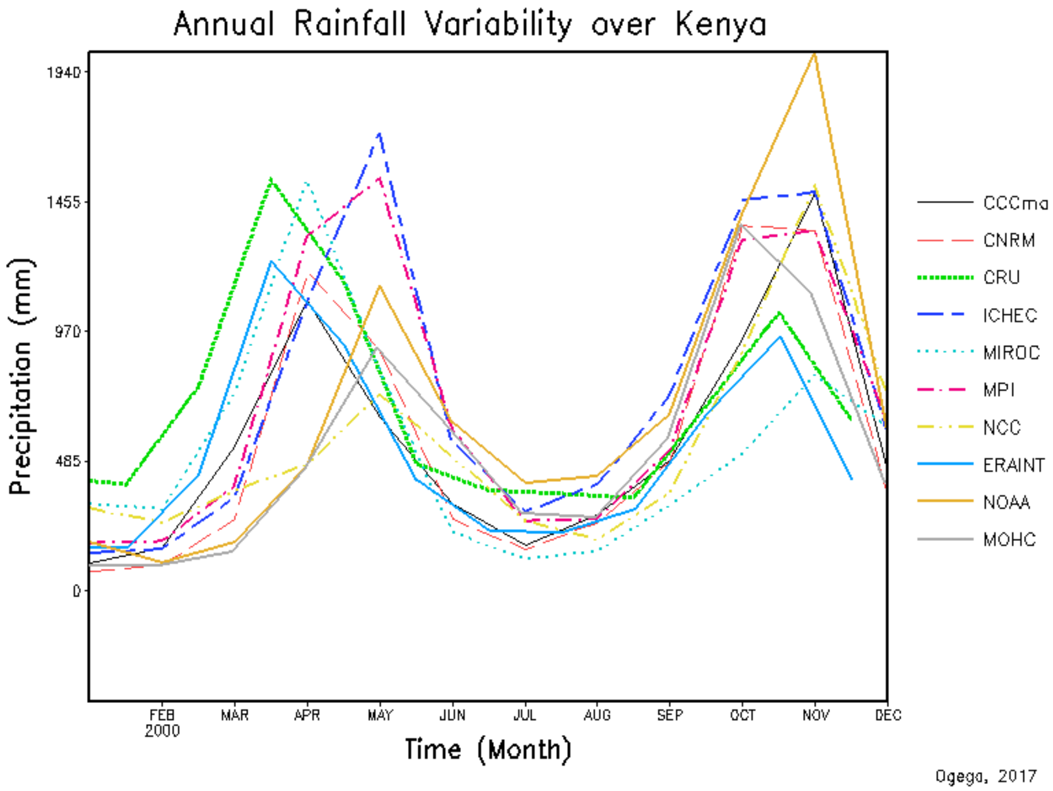

Figure 12: Annual precipitation variability

All the seasons (MAM, JJA, and OND) are well captured by the models, with MIROC being closest to the observed data (CRU) in the MAM season. CCCma and NCC models were closest to the observed data (CRU) in the OND season. The ENSmean for the eight GCMs could simulate the annual cycles of precipitation, but it was less precise compared to CRU data.

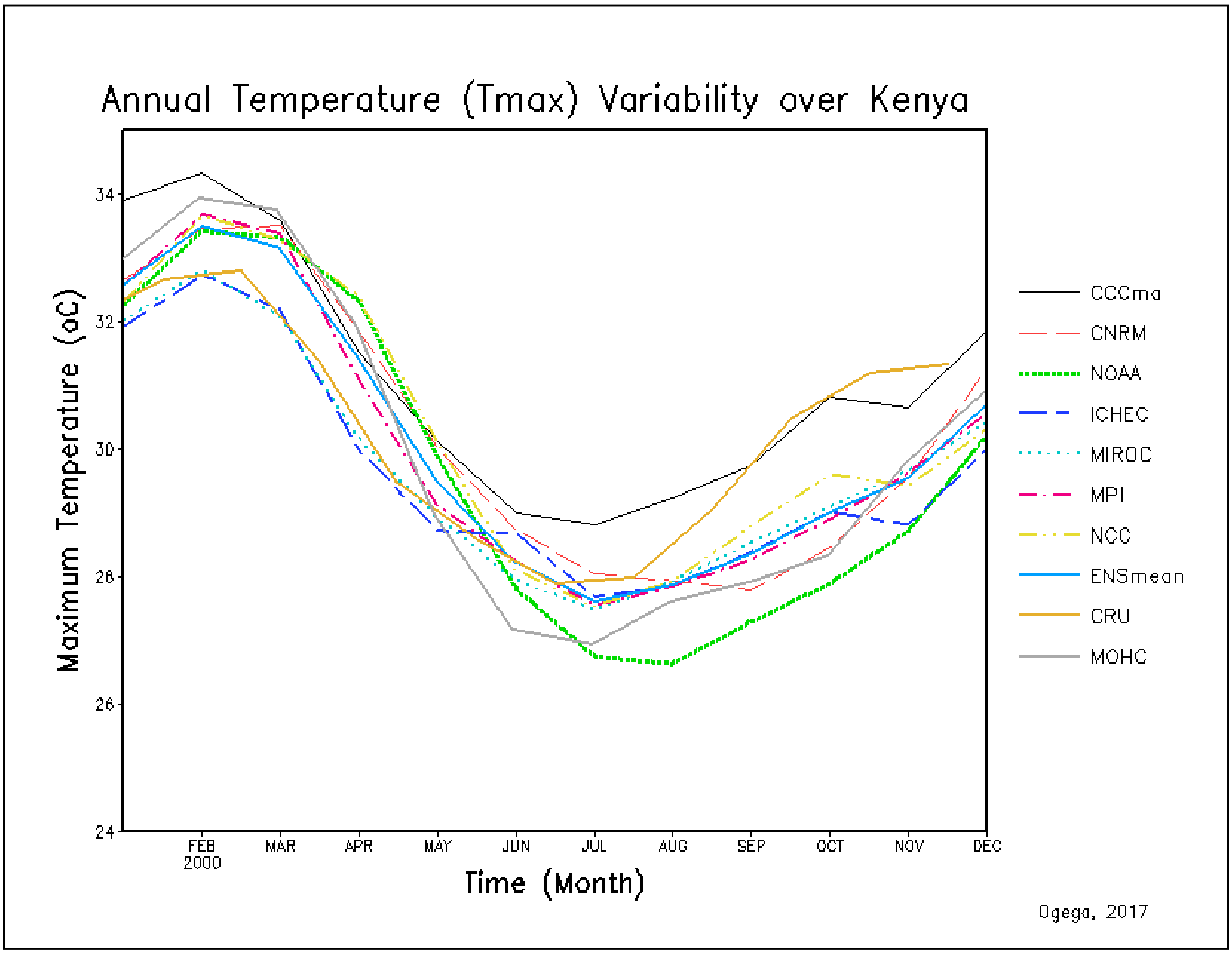

Figure 13: Annual cycle for maximum temperature (Tmax)

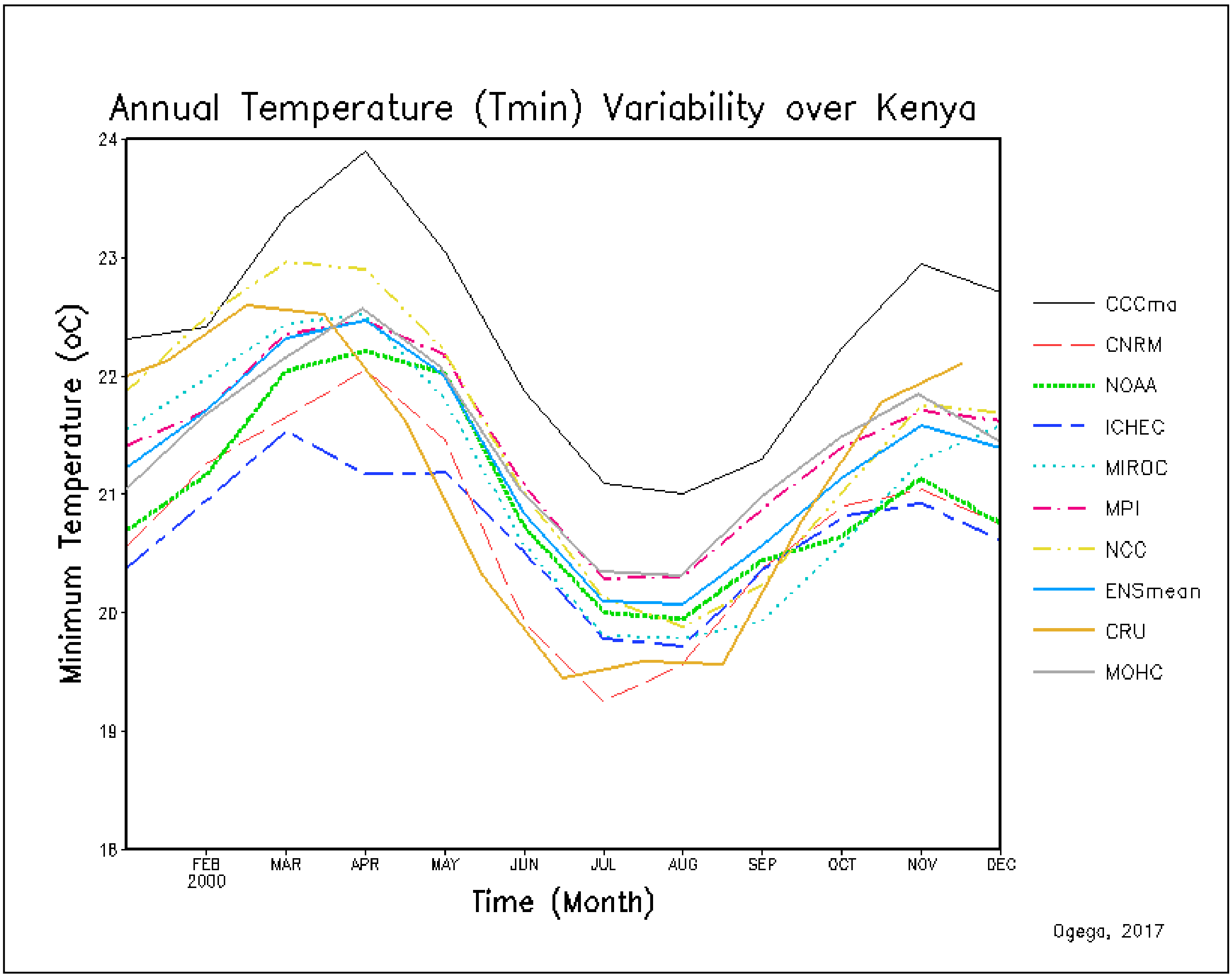

Figure 14: Annual cycle for minimum temperature (Tmin)

For maximum temperature, ICHEC and MIROC were close to the observed data (CRU) for the January to May period, while CCCma was closest to the observed data in the September to December period. For minimum temperature, CNRM was closest to CRU during the MAM period, while NCC was closest in the OND season. Overall, all the models could simulate the study area's temperature well relative to the observed data.

4.2.3 Climate projections

This section provides the RCA CORDEX RCM model projection of the future climate of the study area; based on the baseline climatology.

4.2.3.1 Future Climate Changes

The future changes in climate in the study area were calculated for both RCP 4.5 and RCP 8.5 pathways (for the period 2015 to 2045). As detailed in subsection 4.2.1, projections were generated using the ICHEC, MOHC, MPI, and their mean (ENSmean) as the drivers of the RCA model.

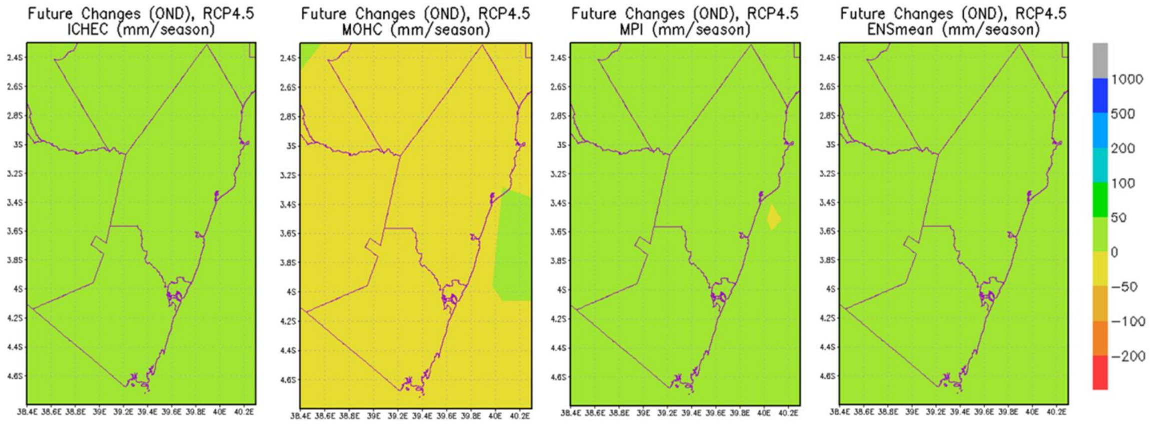

Figure 15: Future changes in OND seasonal rainfall for the period 2015 – 2045 (RCP 4.5)

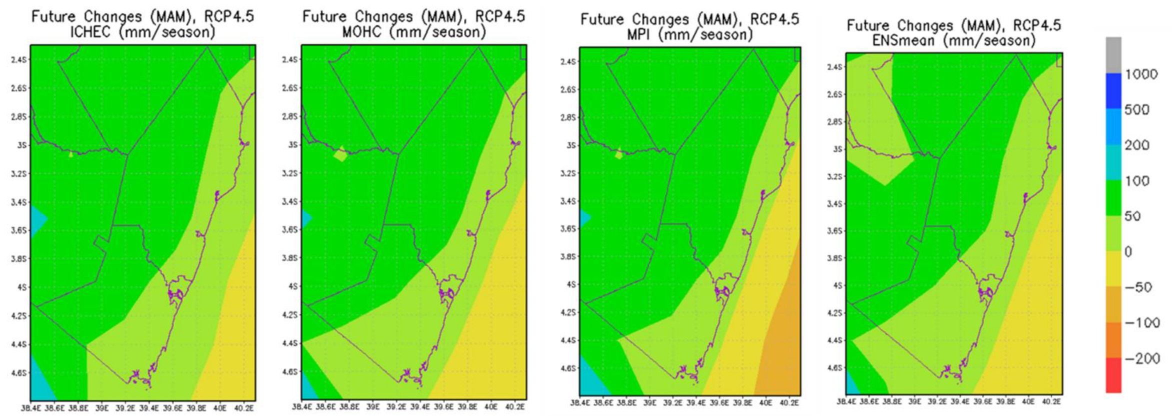

Figure 16: Future changes in MAM season rainfall for the period 2015 – 2045 (RCP 4.5)

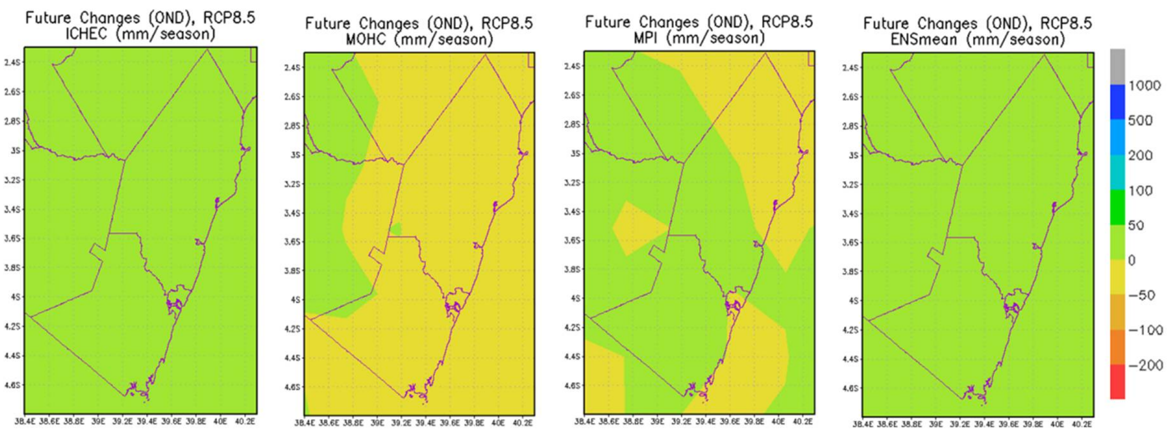

Figure 17: Future changes in OND season rainfall for the period 2015 – 2045 (RCP 8.5)

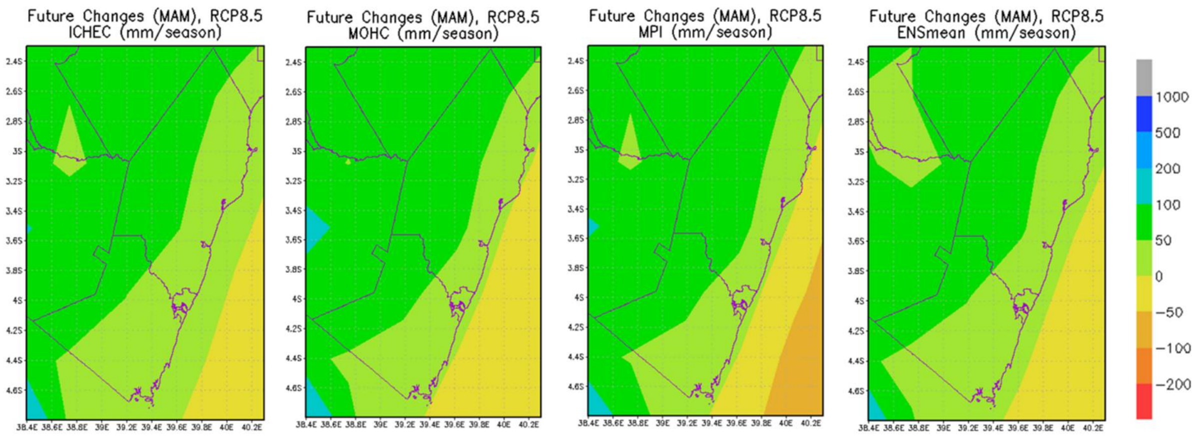

Figure 18: Future changes in MAM season rainfall for the period 2015 – 2045 (RCP 8.5)

As shown on Figure 15, Figure 16, Figure 17, and Figure 18, rainfall in the study area is projected to increase during the period 2015 to 2045; for both RCP 4.5 and RCP 8.5 pathways. This implies that climate impacts caused by a net radiative forcing of +4.5 by 2100 would be felt already before the year 2045. Results from this study were consistent with other model projections for the East Africa region.

Above-normal rainfall may signify the occurrence of floods in usual flood hotspots as well as newer areas. Floods come with impacts such as outbreaks of diseases for animals, plants and human beings. Further, increased precipitation may aggravate sea-level rise, ocean-land infiltration, and increased siltation in the ocean, among other impacts. On the flipside, the increasing rainfall may come as a blessing to the farming communities in the Kenyan coast. Small-holder farming in the Kenyan coast is predominantly rain-fed, and the rains have been increasingly erratic. Increased rains are likely to translate to better yields for the farmers and, hence, enhanced livelihoods and socio-economic prosperity. Either way, resources ought to be mobilized promptly to ensure adequate preparations for the projected increased precipitation.

4.3 Indigenous and historical coping strategies

This section highlights past practices that farmers have been using in their farming. These practices may have been random or intended - a fact that this research sought to establish. The results of this sub-section were obtained from the analysis of semi-structured questionnaires as detailed in subsection 3.1.4. The questionnaire interviews were conducted between October and December 2015.

4.3.1 Demographic features of respondents

Eighty-five percent (85%) of respondents indicated that men headed their households while 59 percent of women respondents stated that heads of families made decisions on the use of their farming land. Thirty five percent (35%) of the female respondents indicated that the entire family made decisions on how to use their land. Most male respondents (94%) assumed the responsibility of household decision making; as heads of their households while 5 percent of male respondents considered decision making as a collective responsibility at household level.

Figure 19 shows the demographic features of respondents interviewed in this study. Fifty-six percent (56%) of respondents were male while 44 percent were female.

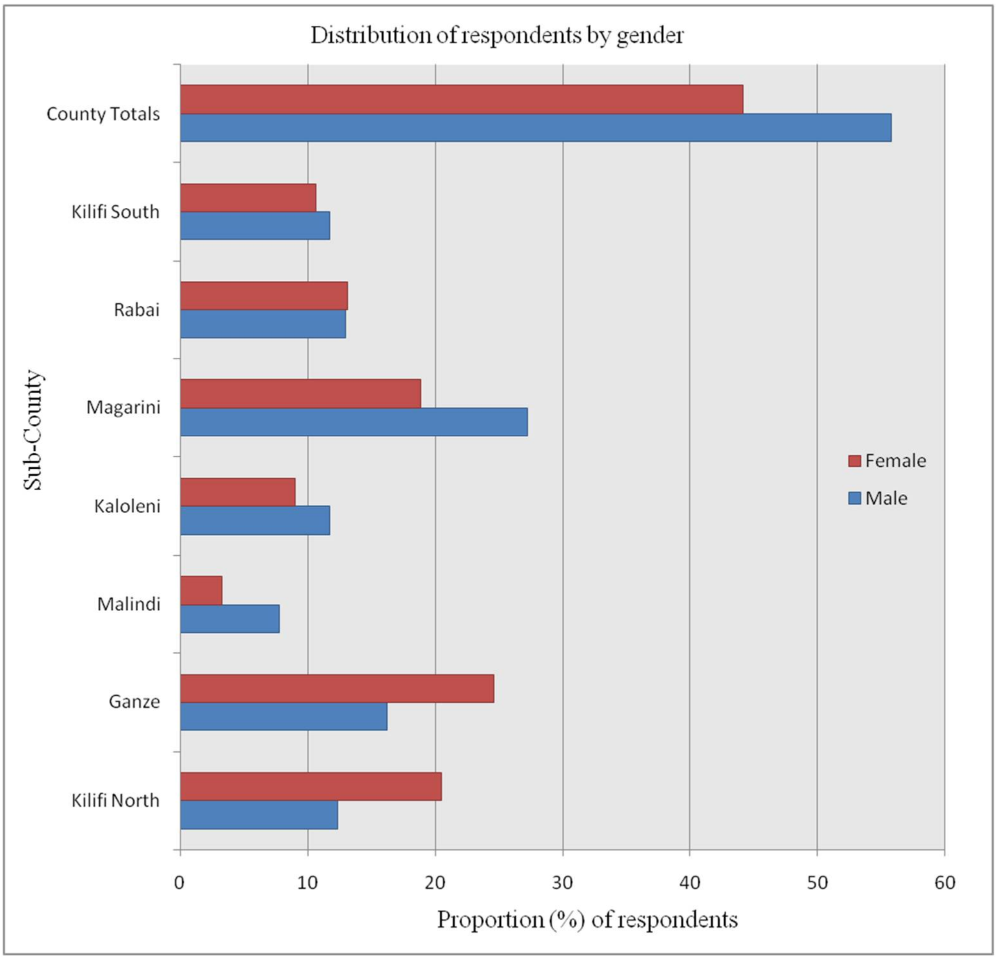

Figure 19: Distribution of respondents by gender per sub-county

Information regarding the gender distribution (as given in Figure 19) is important because different demographic groups are affected differently by climate change and variability. Women and children, for instance, are affected differently from their male counterparts when it comes to mobility. Traditionally, men at the Kenyan coast would move to towns in search of jobs leaving women and children at the villages. In case of adverse impacts of climate change and variability (such as prolonged droughts), women and children are the most affected.

The general tradition in coastal Kenya is that men are the heads of households. Respondents in the social survey remarked that men were the heads of their families and, hence, had the final say on decisions at family level. Figure 20 shows the respondents' levels of education. The majority of those surveyed (both male and female) had gone through some level of formal education. Majority of male respondents (38 percent) had secondary school level education, while many female respondents (34 percent) had some primary school level education.

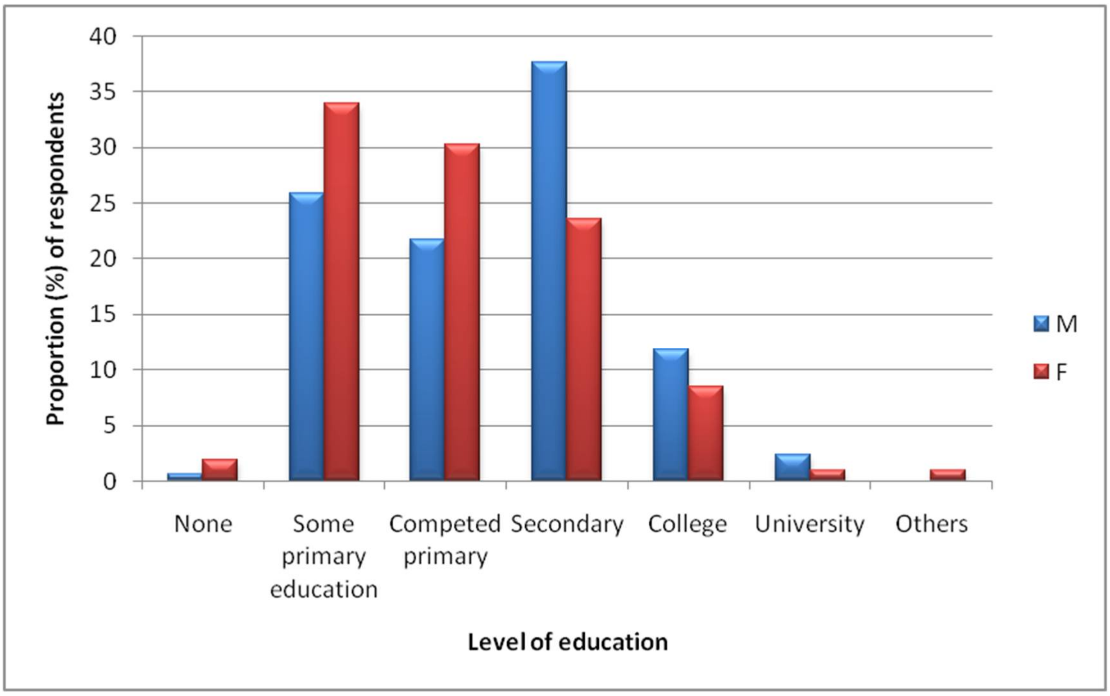

Figure 20: Distribution of respondents by level of education

While the respondents in this study were not selected based on their level of education, respondents' level of education can significantly contribute to the adaptive capacity of a given individual – in case of an extreme weather event. For instance, an educated person has the flexibility to diversify his/her sources of livelihood in case farming becomes less lucrative. Such a person's climate information uptake is also higher compared to another that is not able to, say, read and write.

From Figure 20, most of the respondents (26 percent for males and 34 percent for females) had some basic education (primary and secondary school levels). This may limit their ability to diversify to other sources of livelihood such as formal employment. As a result, many households in Kilifi County are likely to rely (almost entirely) on farming. Any changes regarding climate change and variability are likely to affect the people of Kilifi County and the coastal region at large.

4.3.2 Socio-economic features of respondents

Figure 21 shows a county summary of the socio-economic features of respondents.

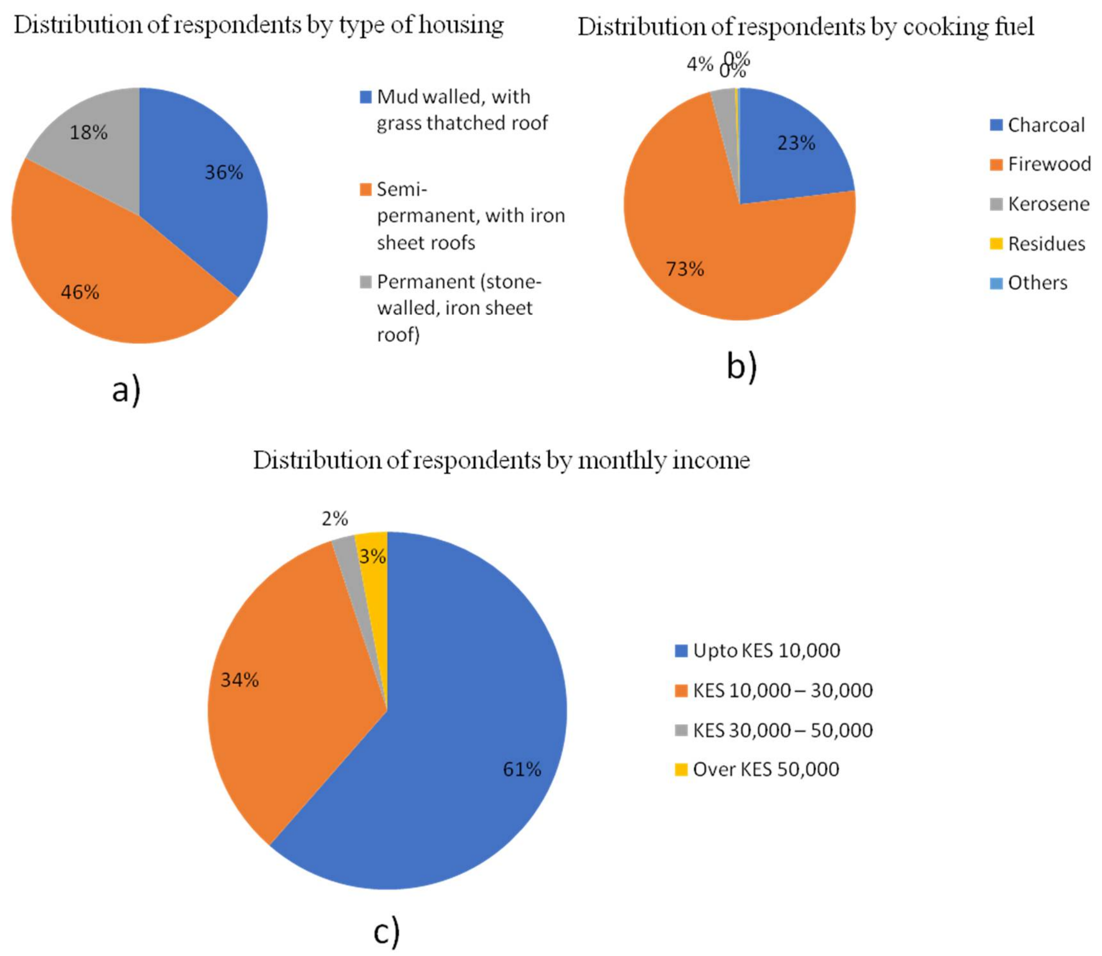

Figure 21: Distribution of respondents by type of housing, main cooking fuel & mean monthly income

From Figure 21*c*, 61 percent of respondents' monthly income was approximately KES 10,000 (according to the respondents' own approximation). However, many respondents alluded to a lack of efficient formal system of accounting for their earnings. Some of them would produce goods and consume them without money exchanging hands. This implies that households in Kilifi County have a limited possibility to diversify their sources of livelihood due to the limited capital. With a monthly income of KES 10,000, one would find it difficult to procure a greenhouse with irrigation equipment – for example. Notably, the monthly revenue is used for various reasons such as paying school fees, buying supplementary food. Any additional stress on the household income brought about by climate variability, and change is likely to adversely affect households.

Figure 21a indicates that 46 percent of respondents lived in semi-permanent (mud-walled houses, but with iron sheet roofs) houses while 36 per cent of the households lived in mud-walled and grass-thatched houses. Seventy-three percent (73%) of households used firewood for cooking, while 23 percent used charcoal as their primary source of fuel for the kitchen. Some of the respondents used both charcoal and firewood (Figure 21*b*). Kilifi County is, mainly, an arid or semi-arid area. An extensive use of firewood and charcoal for cooking may deplete the few existing trees and shrubs. This, as a result, is likely to diminish vital ecosystem goods and services that forests bring such as nutrient cycling and purification. An analysis on the respondents' type of housing and cooking fuel highlighted prevailing standards of living over the study area. If the respondents were unable to afford decent housing and modern cooking fuel (such as liquidated petroleum gas), it was least likely that these respondents had sufficient resources to invest in climate change adaptation.

The statistics on types of housing for households and their location was particularly important to note due to exposure to risk reasons. For instance, households living in mud-walled houses situated at lowlands and river valleys would be exposed to the impacts of floods. Those living near the ocean banks would be exposed to the effects of ocean infiltration or even sea-level rise. Only 18 percent of households lived in permanent houses (Figure 21a). This implies that the rest (82%) would be exposed to impacts of above-normal rains; if they were to happen.

Fifty-six percent (56%) of respondents indicated crop farming as their primary source of livelihood (as shown on Figure 22). This implies that any changes in weather and climate in the county were likely to affect the socio-economic well-being of the community and the region. Further, farming practices in Kilifi County were predominantly traditional and ineffective; often inferior to modern farming practices. Measures need to be put in place to help farmers efficiently use modern farming practices for improved agricultural production.

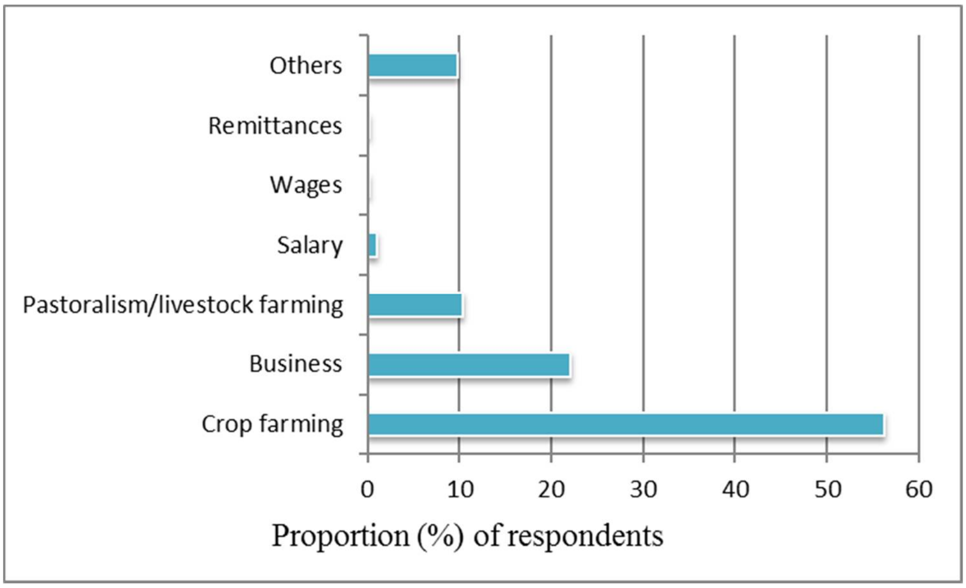

Figure 22: Distribution of households by source of livelihood.

From Figure 22, most of the farmland was used for crop cultivation. Households allocated less than 3 acres of their land for grazing and growing pasture. Growing of trees was also given very minimal acreage (less than 3 acres of land). This could imply that many households were clearing forest cover to create room for crop cultivation. The small proportions allocated to grazing or growing of pasture could also mean that families were rearing less livestock. This highlights a diversification gap that could be explored for better agricultural productivity. Practices such as agroforestry and organic farming would help in replenishing agro-ecosystems, as well as increase yields for farmers.

Table 4: Distribution of land according to various land use activities.

Land utilization	Size of land	Kilifi County totals (percentage)
Crop cultivation	Less than 1 acre	4
	1 – 3 acres	62
	4 - 5 acres	20
	6 – 10 acres	12
	Over 10 acres	2
Pasture	Less than 1 acre	95
	1 – 3 acres	4
	4 - 5 acres	0
	6 – 10 acres	0
	Over 10 acres	-
Tree cover	Less than 1 acre	74
	1 – 3 acres	23
	4 - 5 acres	2
	6 – 10 acres	1
	Over 10 acres	0

Regarding the distribution of households according to their land utilization (**Error! Reference source not found.**), most respondents (62%) had between 1 and 3 acres of land. Seventy-four percent (74%) of the households interviewed spared less than 1 acre of their farms for trees, while 95% of the households spared less than 1 acre of their farm for pasture. This showed a need for farmers in Kilifi County to diversify in their farming. Farmers need to allocate more portions of their land for growing trees and pasture. Agroforestry is one of the modern agricultural practices that enhance productivity – a practice that farmers in Kilifi should embrace. Maize was a predominant crop grown by household under study. Mixed farming, where farmers cultivated crops while rearing livestock at the same time, was also common. It is for this reason that some respondents found it difficult to quantify the exact proportions of their farm that was used for various land uses.

4.3.3 Institutional factors

Wasserman *et al.* (1994) define a social network as a group that consists of a finite set of actors defined by a given relation or relations. Some of the benefits of social networks include the creation of social support systems. These social supports can provide buffers against internal and external stressors that affect members (House *et al.*, 1998; Zilberberg, 2011). For instance, members of a given social network can fundraise amongst themselves to raise capital for a business venture.

Such activities make it possible for members to do some activities that they would, otherwise, find difficult to do on their own. On the other hand, social networks may at times impact negatively on their members (Cattell, 2001; Arthur 2002). For instance, a given social network can conspire to resist influence from a given institution such as a County government. This calls for participatory and consultative processes involving all stakeholders to avoid the risk of interventions being resisted.

In this study, many respondents (86%) belonged to one or more social networks. These networks were, mainly, farmer groupings aimed at sensitizing farmers on farming practices. Some networks were, however, meant to provide social support functions such as petty financing and money saving. Many respondents expressed their appreciation for the help that they were getting from their social networks. From farmer field schools to access to agricultural extension services and financing options, respondents had all the reasons to join their social networks. The idea of social networks in the study area is welcome due to their ability to bridge the gaps that previous administrations had not been able to cover. Issues of marginalization, low literacy levels and poverty (among other stressors) had seen many farmers from the Kenyan coast struggle with their farming.

Many respondents (46%) acknowledged receipt of agricultural extension services aimed at boosting their agricultural activities (Figure 23). These extension services came from government (both the national government and the county government). Many respondents indicated that most of the extension services focused on giving information to farmers. The respondents, however, stated that there was a need to provide capital and equipment to the farmers to enable them to improve their farming.

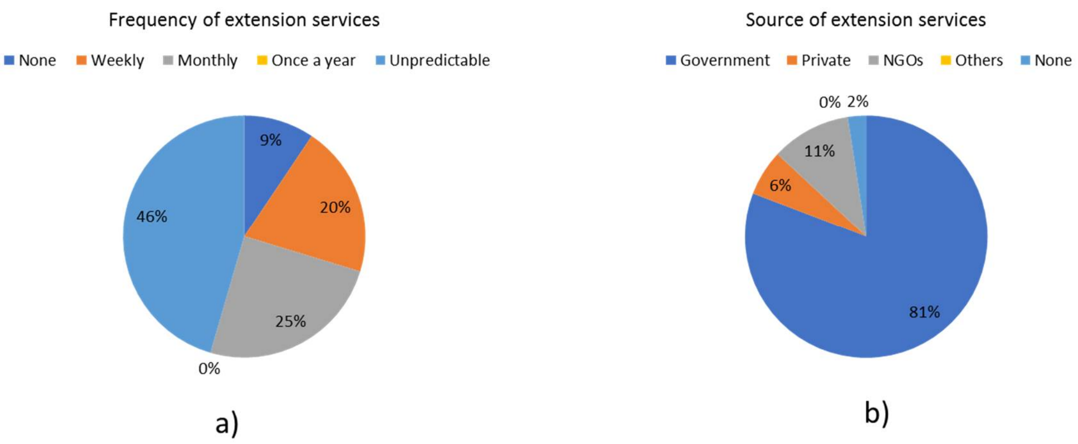

Figure 23: Distribution of respondents by access to extension services

4.3.4 Food security

This sub-section sought to assess the households' perception of their food security status. The availability of food throughout the year was taken as an indicator of a household's food security. Respondents were asked if they experienced any shortages of food at any given time of the year. Those that experienced food shortages were asked if they could buy food to supplement their harvests. They were also asked if they could access markets to buy food, and if the food was available in the markets. These factors then helped respondents say what they perceived to be their food security status.

Maize, cassava, cowpeas and cashew nuts are some of the main food crops that the respondents grew – with maize being predominant.

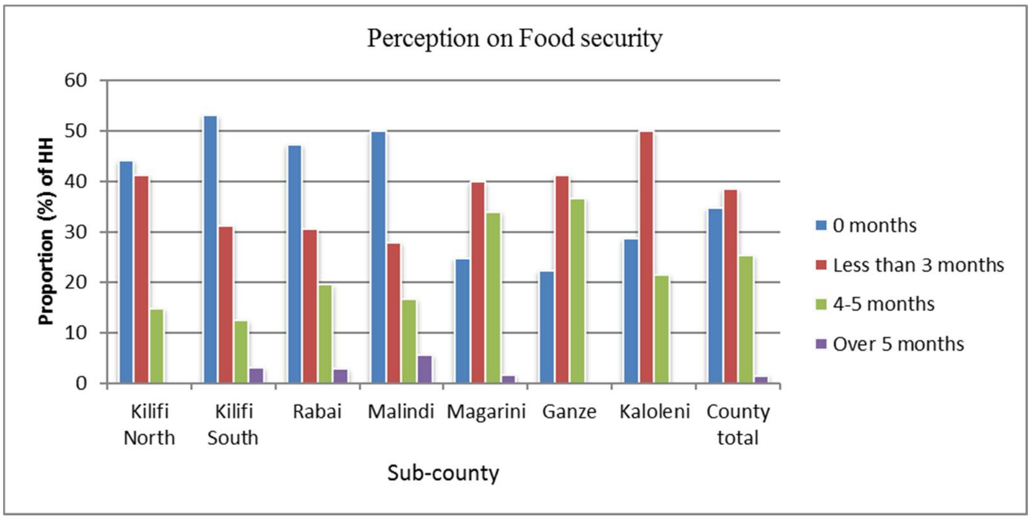

Figure 24: Distribution of respondents according to their perception on their food security

From Figure 24, about 35 percent of the respondents in Kilifi County considered themselves to be food secure; they had enough food for their consumption all year round. Sixty five percent (65%) of the interviewees perceived themselves as being food insecure. Many households from Kilifi North, Kilifi South, Rabai and Malindi sub-counties considered themselves to be food secure. This can be attributed the sub-counties being tourist destinations with some members of households interviewed working in the tourism industry.

Respondents who considered themselves as food insecure cited drought as the main reason for their food insecurity (86%). Seven percent (7%) blamed it on unproductive/insufficient land, 3% cited a lack of farm inputs and 3% cited floods as the causes of their food insecurity. From this statistic, drought or insufficient rainfall was the most pronounced weather and climate related phenomenon. This agrees with the scientific information generated in objective 1 of this study. From the observed climate, rainfall over Kilifi County has a trend towards below average. Further, respondents cited a change in the timing of the rains which (as a result) affect their planting dates and, hence, yield.

4.3.5 Perceived indicators of climate change and variability

This subsection aimed at finding out the leading indicators that respondents could attribute to climate change and variability. This study considered rainfall and temperature as the main climate variables. Regarding precipitation, 87 percent of respondents perceived a decrease in rainfall over the years. Others indicated a change in timing of the rains (5%), an increase in the rains (5%) while 3% of the respondents cited both a decrease in rains and a change in timing of the rains. Figure 25 gives a summary of the results. The respondents' perceptions correspond to observed climate trends discussed in subsection 4.1.2.

Concerning temperature, 97% of the respondents cited an increase in temperature over the years. Some respondents (2%) thought that temperature had decreased over time, while 1 percent of the interviewees thought that temperature had become more extreme. Figure 26 gives a summary of the results. The respondents' perceptions on temperature were in tandem with observed temperature trends presented in subsection 4.1.2.

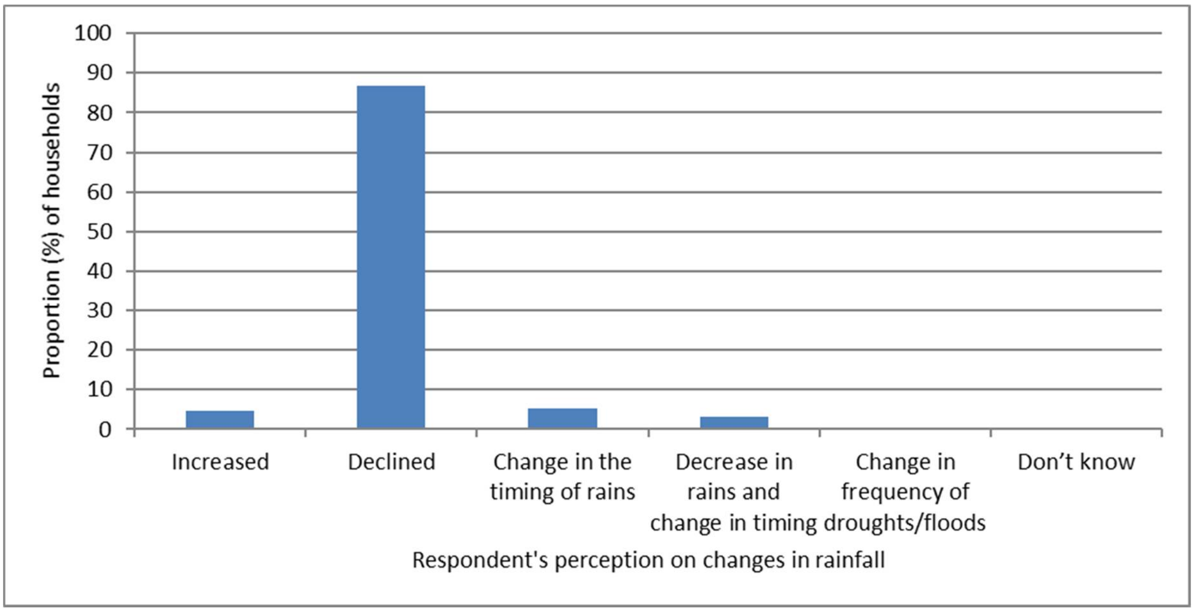

Figure 25: Distribution of respondents according to perception on changes in rainfall

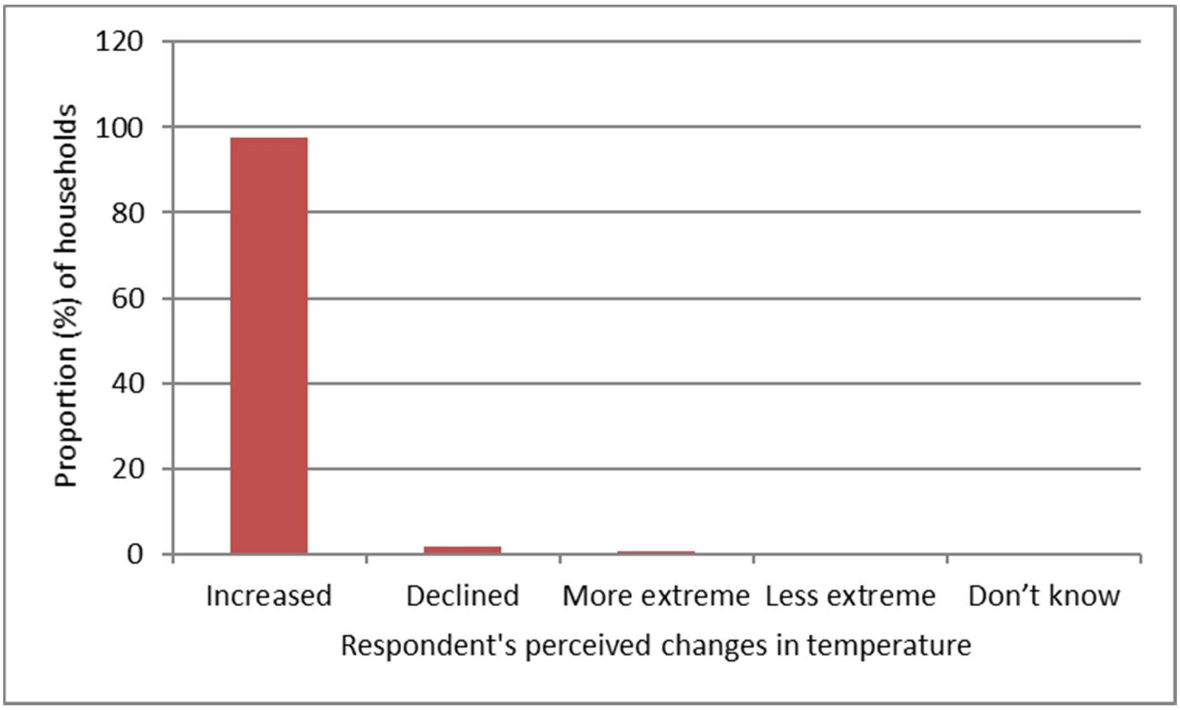

Figure 26: Distribution of respondents according to perception on changes in temperature

4.3.5.1 Respondents' perceptions on impacts of climate change and variability

This subsection sought to find out if the households under study had experienced any impacts of climate change. They were given options to choose from, but they could also provide responses that may not have been captured in the options given. According to the respondents in the study, climate change and variability has been experienced in Kilifi County over the years. The clearest

(79 percent of respondents) manifestation of climate change impacts identified by respondents was the perennial crop failure. Figure 27 below depicts indicators of the impacts of climate change and variability as identified by those interviewed.

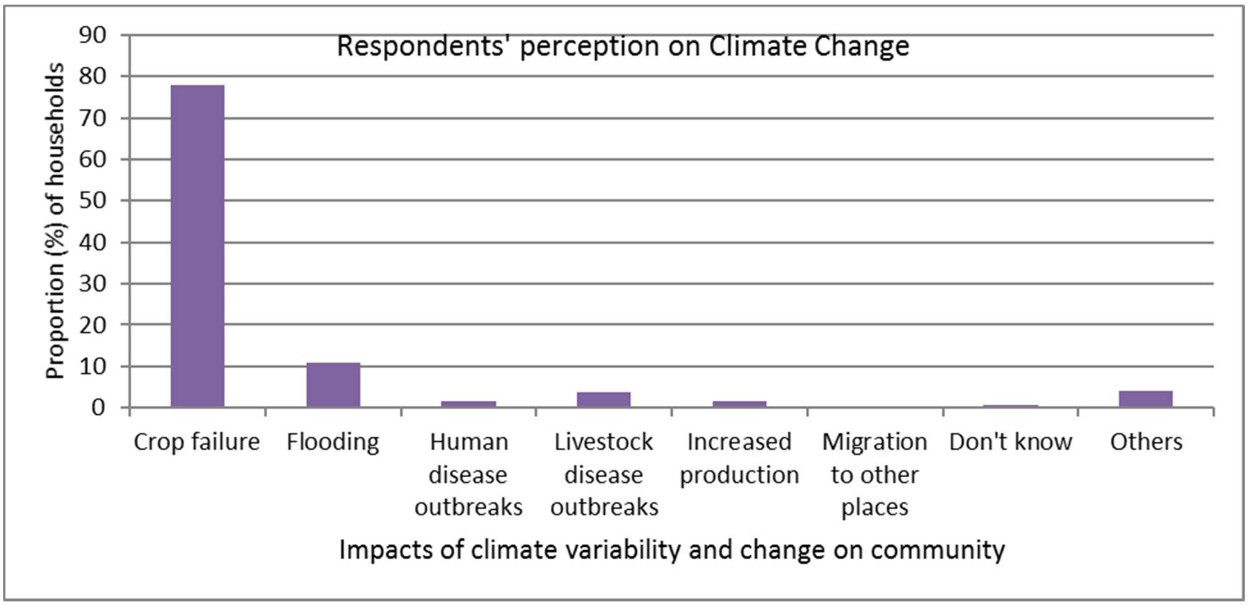

Figure 27: Distribution of respondents by their perceived indicators of climate change

From Figure 27, most households (78%) cited crop failure as the powerful impact of climate change and variability in their area. About 11 percent of the respondents cited flooding while 3.6% of the interviewees cited emergency and re-emergency of livestock diseases. Other impacts included human disease outbreaks (2%), and increased yield production (2%). The respondents that cited increased yield production attributed it to the adoption of better farming techniques such as climate-smart agriculture. Improved access to agricultural extension services was also attributed to the increased crop yields.

4.3.5.2 Historical coping strategies used by farmers against a changing climate

Many households at the Kenyan coast (77% of respondents) have been taking measures aimed at coping with the impacts of climate change and variability. Most of the adjustments made were a departure from indigenous ways of farming. This was attributed to various campaigns that were being run by actors such as the county governments and Non-governmental organizations like the Food and Agricultural Organization (FAO). Figure 28 below shows proportion of households that had made some adjustments in their farming, while Figure 29 shows the changes that had been made.

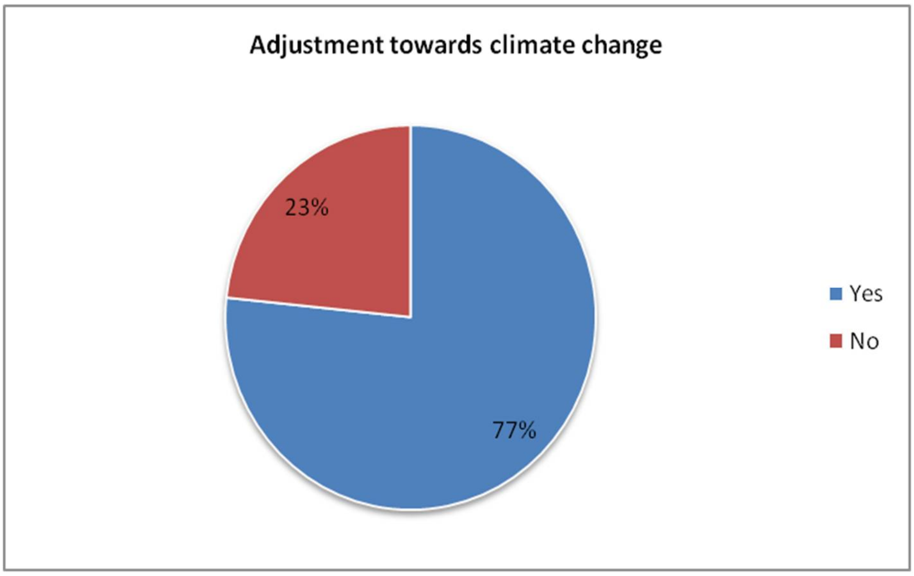

Figure 28: Adjustments made to farming practices due to climatic changes

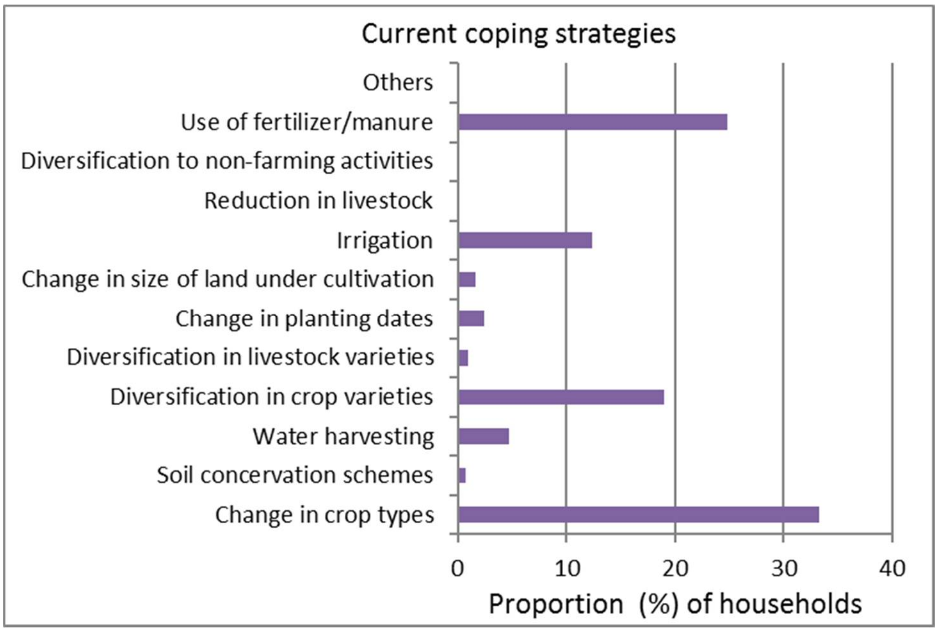

Figure 29: Proportion of households per adjustment item

Change in crop varieties, use of fertilizer/manure, diversification in crop types and irrigation were the most pronounced adjustments made by respondents. The question on changes made to a changing climate and traditional coping strategies was raised during the FGDs. As shown on the FGD reports (Appendix iii), a shift to organic farming was said to be a common practice. Some farmers were now more reluctant to use some farm inputs such as fertilizers which were reported to deplete soils.

The FGDs identified some indigenous ways of weather forecasting that are used to inform farming activities in the Kenyan coast. One of these ways is the observation of the behaviour of birds. For instance, the presence of migratory birds flying high in a given area would signify good weather. Birds resting on mangroves for a long time would signify the coming of bad weather.

The presence of some particular fish species in the Indian Ocean, spotted by fishermen, is also used to predict the future weather. The presence of lobster and octopus in the fishing basket traps would indicate bad weather in the coming days. An appearance of particular star patterns in the sky would also provide information on whether a dry or wet season would be expected. The appearance of rainbows was said to indicate an ending rain season while swaying of tree leaves in a particular way would mean the coming of the rains.

Often, specific older members of the community were charged with the responsibility of weather and climate prediction. These older members draw their knowledge from their forefathers and many years of experience. Their weather predictions were said to be accurate over the years. The elders were supposed to command considerable following from their communities. For these reasons, scientists should find a way of working together with the traditional weather forecasters. In so doing, weather (and by extension climate) prediction is likely to be better. This will also foster the participation of all actors (including communities) in knowledge generation, interpretation, and consumption.

4.4 Proposing appropriate adaptation strategies

This study objective was realized using the semi-structured questionnaires and the focus group discussions (FGDs). After analysing the findings of the inquiries (as discussed in objective two above), FGD questions were formulated (Appendix i), and FGDs conducted as discussed in subsection 3.2.4. This section gives a summary of the findings of the FGDs, and highlights on proposed adaptation strategies to be used at the Kenyan coast in the face of a changing climate.

4.4.1 Summarized FGD findings

The common consensus was that climate change and variability was real and being experienced at the Kenyan coast. This was consistent with the results of questionnaire interviews, the FGDs, and the climatological data analysis. Some of the indicators of a changing climate on the Kenyan coast include reduced rainfall, a change in rainfall patterns and increased temperature. These changes in climate had caused impacts such as crop failure, emergency, and re-emergency of pests and diseases. Technical Institutions such as NDMA and KACCAL confirmed that scientific records/statistics records available were consistent with the observations made by farmers.

Various stakeholders were making some adjustments to help farmers cope with the changing climate. These changes include some sporadic organic farming (mainly minimizing the use of chemical-containing inputs such as fertilizers and sprays) and adoption of modern agricultural practices. Diversification from traditionally grown food crops (such as maize) to new crops such as cassava and passion fruits was also being done. Besides, there was increased awareness on and uptake of climate-smart agriculture initiatives including the concept of conservation agriculture that was being championed in the study area by FAO. However, adaptation options that had been initiated on the ground ought to be practised properly and in a sufficient scale for significant results.

On the flipside, some adaptation efforts that were being implemented by some actors were said to be achieving minimal success. These efforts include supply of subsidized seed variety (by the County Governments) such as PH1. This maize seed variety was said not to be doing well, and the quantity of seeds supplied was minimal. There was, also, concern on the initiative for the County Governments to plough farms at subsidized rates for the farmers. Farmers would have their farms ploughed but miss farm inputs, or even markets for their produce – leading to losses.

Duplication of efforts was also seen as a problem in adapting to the changing climate. Efficient strategies for mobilizing and managing interventions seemed to be lacking. Civic education and awareness campaigns being carried out over the study area were found to be insufficient. There was need to diversify media channel to ensure that information penetration reached all the farmers. In addition to that, some services such as soil analysis were said to be too expensive for many farmers. There was a need to provide such services at a more affordable cost to enable as many farmers as possible to access them.

Further, it was observed that too few agriculture extension officers were available to cover the entire county (efficiently and on time). However, farmers made little effort in seeking climate information that could inform their farming activities. It was remarked that relief food that was supplied by local authorities over the study area minimized the need to work hard for optimum agricultural production for some members of the community. Extension services for the farmers was said to be difficult in some areas because some farmers demanded payment to attend seminars/workshops meant to help them in their farming. This made it difficult for outreach/fieldwork activities to prosper.

4.4.2 Appropriate and sustainable adaptation strategies in a changing climate

Various suggestions were made on what would be the most suitable and sustainable adaptation strategies for farmers at the Kenyan coast. The first one, probably the most important strategy, was the formulation of a comprehensive adaptation framework for the Kenyan coast. The framework should provide for a coordinated approach to coastal adaptation. Hitherto, actors have been playing their parts but in isolation. For instance, County Governments have been providing subsidized seeds to farmers, but no markets for the increased production. According to the farmers, a comprehensive framework would reduce the risk of leaving interventions halfway through. It would also bring all the required actors (such as the suppliers, the markets, the farmers and the government) together for a common cause. In so doing, adaptation efforts will be useful and beneficial to all stakeholders.

The second adaptation strategy was an efficient irrigation system practised on a significant scale. Farming at the Kenyan coast has been predominantly rain-fed. With the increasingly unpredictable and reduced rains, a reduction in reliance on rain-fed agriculture is paramount. While some efforts have been made to promote irrigation, many farmers have not been taken on board. There was a need to upscale irrigation activities so as to reach as many farmers as possible. For instance, the County Governments could engage suppliers and find ways of supplying irrigation equipment to farmers at more affordable prices. Farmers should also be trained and facilitated to do water harvesting for irrigation purposes. This strategy will reduce crop yield losses emanating from erratic rains.

Agroforestry is another adaptation strategy that was identified to suit the Kenyan coast. Agroforestry is defined as a deliberate integration of trees and shrubs into animal and crop farming systems with the aim of creating economic, environmental and social benefits (USDA, 2013). A land management system can only be called agro forestry if it is intentional, intensive, integrated and interactive (USDA, 2013). It can be subdivided into silvopasture, alley cropping, forest farming, windbreaks and riparian forest buffers.

Silvopasture is a combination of trees with livestock and their forages while alley cropping refers to planting crops between tree rows as the trees grow. Forest farming entails growing food and other crops under a managed forest canopy, Windbreaks shelter animals, plants, soil and buildings from snow, dust, and wind. Riparian forest buffers are natural or re-established areas along streams and rivers comprised of shrubs, trees, and grass.

By embracing agro-forestry, farmers at the Kenyan coast would increase their agricultural productivity while taking care of their environment. Fruit trees such as mangos and avocados could increase food production, and provide an additional source of income for the farmers. The trees could also be used for timber and firewood hence reducing the risk of depletion of the few existing shrubs and forests. Diversification of crop types and varieties would go a long way in adapting to the changes in climate. Farmers ought to switch from traditionally grown crops such as maize (which are less drought tolerant) to crops such as cassava which are more drought tolerant. Agricultural research organizations should enhance their research and provide farmers with suitable plant seed varieties for various agro-ecological zones. This will help minimize yield losses, and improve food security.

4.4.2.1 An integrated climate change adaptation framework for coastal farmers in Kenya

As discussed in subsection 4.4.2, an integrated climate change adaptation framework would be critical in robust climate change adaptation strategies. An adaptation continuum (Table 5
Table 5) was used to evaluate the motivation behind climate change adaptation interventions that were being implemented at the Kenyan coast. The adaptation continuum revealed that most initiatives were conceptualized as measures to address drivers of vulnerability with minimal reference to climate change. Further, at the county level, there was no climate change adaptation plan or a mechanism to determine the effectiveness of county initiated interventions towards addressing climate change-induced extremes such as prolonged droughts.

Table 5: The adaptation Continuum (adapted from Schipper *et al.*, 2007)

Vulnerability Focus ⟵⟶ Impact Focus

Addressing drivers of vulnerability	Building response capacity	Managing climate risks	Confronting climate change
Focus on reduction of poverty and addressing other non-climatic stressors that make people vulnerable i.e. address conventional development challenges such as access to clean water.	Focus on building robust mechanisms, such as pro-smallholder farmers' livestock and crop insurance schemes, for problem solving	Focus on the incorporation of climate information into decision-making. This can be done by ensuring equitable representation and participation of all stakeholders - including smallholder farmers – in the policy formulation and implementation process.	Focus exclusively on climate change-associated impacts including prolonged droughts

Figure 30 shows an integrated climate change adaptation framework. The framework is based on findings of the FGDs that highlighted the need for a well-coordinated adaptation mechanism. The figure begins from proposed adaptation measures; informed by accurate and updated climate change information and best practice climate-smart agriculture (CSA) solutions. The climate information and the CSA solutions are localized to fit a given locality of interest. For these adaptation measures to thrive, there must be an enabling environment (what is referred to as Enablers in Figure 30). Some of the enablers identified for the Kenyan coast include ready markets, robust pro-agribusiness policies, effective business management expertise, insurance and value addition. In a good enabling environment, the proposed appropriate adaptation measures are likely to lead to sustainable adaptation. The indicators of sustainable adaptation include improved crop yields, improved food security, thriving agribusinesses and improved livelihoods. The interplay between proposed adaptation measures, enablers and sustainable adaptation would only be fully realized with a robust coordination and implementation taskforce (referred to as an implementation taskforce in Figure 30). The taskforce comprises of the academia to generate climate information, the government to formulate and implement enabling policies, the farmers who are the primary beneficiaries of the framework and the market that consumes the farmers' produce.

Appropriate climate change adaption measures are informed by the availability of current and pertinent climate information, and the formation of innovative and relevant Climate-smart Agriculture solutions. These adaptation strategies are made possible through a set of carefully blended enablers. These enablers include ready markets, robust pro-agribusiness policies, business management, insurance and value addition services. In so doing, sustainable adaptation will be possible – indicated by improved farm yields, improved food security, prosperous agribusiness, and improved livelihoods.

An implementation taskforce is vital in coordinating various aspects of the framework. The taskforce is comprised of the academia (professionals in the area of climate and environmental science), the government, farmer representatives and the market. The Academia provides current information and knowledge on weather and climate. The government provides policy formulation and implementation direction to make it possible for the framework to work. Farmer representatives will provide practical information and feedback straight from the farms to enhance the applicability of the framework. The market representatives (business executives) will provide information on the current demand and supply trends in the market and how the framework would achieve a competitive and sustainability advantage.

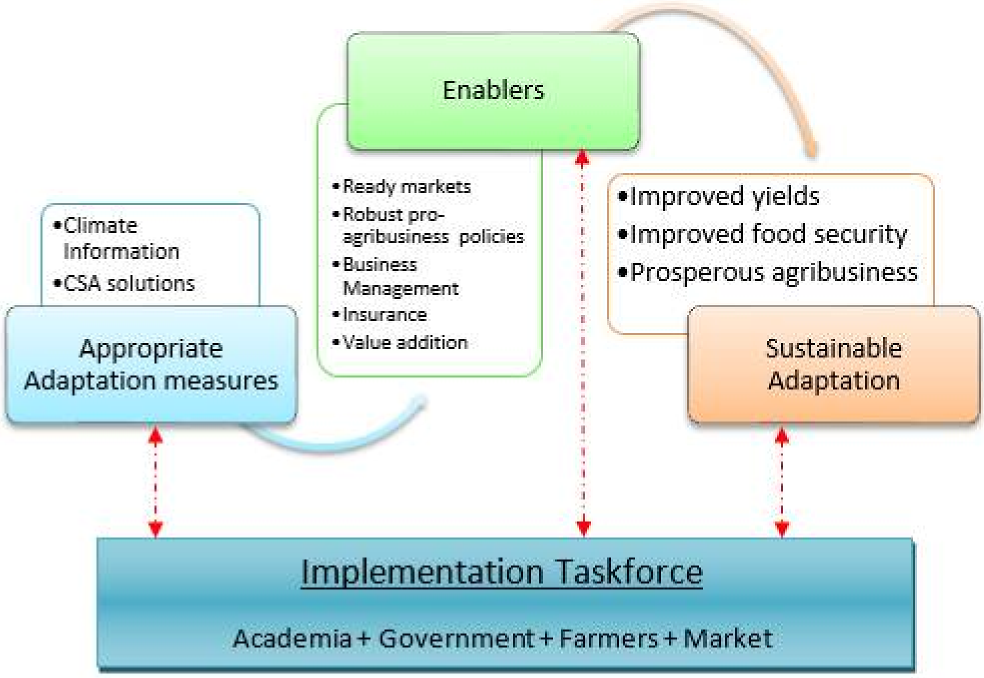

Figure 30: An integrated adaptation framework for the Kenyan coast

4.4.2.2 Pre-requisites for appropriate and sustainable adaptation in the Kenyan coast

Various actions were identified as critical enablers of the identified adaptation strategies. First, there was a need for better-coordinated interventions aimed at helping farmers adapt to the changing climate. This would minimize the risk of duplication of efforts, and ensure that interventions made achieve the maximum impacts. Secondly, the government ought to avail more affordable and economically viable inputs for the farmers. This would increase agricultural production, and make agriculture more rewarding and attractive.

Besides, farmers identified a need for more robust land management policies. At the time of this research land ownership, and utilization was not well managed. Some people owned huge chunks of idle land. There were cases of some property owners being reluctant to lease their unused land for agricultural production. With robust land management policies, the land would be better managed, and more land availed for agricultural production.

Creation of new markets with the interests of farmers at heart increased civic education, and awareness were identified as other as pre-requisites. Others include the promotion of sustainable farming practices, and enhanced value addition services. Retrogressive traditional practices such as witchcraft were identified as barriers to successful agribusiness at the Kenyan coast. There was a need to sensitize the communities against such practices to minimize the risk of having farmers quit farming. With these measures in place, achieving any realistic, sustainable adaptation against the changing climate at the Kenyan coast would be possible.

Regional Climate Models (RCMs) are projecting increased rainfall in East Africa. As discussed in subsection4.2.3, the study area (Kenyan coast) is also likely to experience increased rainfall. This increasing rainfall demands a concerted effort from all the actors in the region to ensure that adequate measures are instituted in time. In so doing, the Kenyan coast is likely to minimize the risks associated with rainfall variability and change. Increased precipitation, also, provides opportunities that be exploited for the socio-economic prosperity of the region.

CHAPTER FIVE

5 CONCLUSION AND RECOMMENDATIONS

This chapter presents conclusions and recommendations of the study.

5.1 Conclusion

Historical climate trends over the study area were determined. Rainfall was found to have declined during the 1961 to 2010. Average temperature (minimum and maximum temperatures) recorded an increase during the period 1961 to 2012. The decrease in rainfall totals (both annual and seasonal totals) could be a contributor to perennial dwindling of crop yields over the study area. An average temperature increase over the study area coupled with decreased rainfall could have caused prolonged droughts that may have caused reduced crop yields.

Future rainfall projections over the study area were generated using the CORDEX RCA RCM. Results showed that rainfall was expected to increase for the period 2015 to 2045; for both RCP 4.5 and 8.5 pathways. If the rainfall projections come to pass, the study area shall experience reversed rainfall trends relative to the 1961 to 2010 period. The rainfall increase is likely to enhance agricultural productivity especially in areas that have always experienced depressed rainfall over time. However, the increased rainfall could also cause crop failure, destruction of property and life due to potential floods and sea level rise. Nevertheless, adequate preparation could enable smallholder farmers at the study area to harness full potential of the expected rainfall.

Historical climate change coping and adaptation strategies, and their effectiveness, were evaluated. Overall, few climate change adaptation initiatives over the study area were identified. However, the initiatives had achieved little success. Many farmers were either unaware of appropriate adaptation options or were unable to implement effective climate change adaptation options. The findings of this objective imply that historical coping and adaptation strategies over the study area were ineffective and, for this reason, there was need for more appropriate and effective adaptation options for improved agricultural productivity.

Based on historical and projected climate over the study area, and the findings from community surveys, appropriate climate change adaptation measures were proposed. These adaptation measures combined both the indigenous and scientific knowledge. A localised and integrated climate change adaptation framework was generated. The framework is likely to provide a vital platform on which stakeholders could initiate effective adaptation strategies for improved agricultural productivity and, hence, socioeconomic development of the study area.

5.2 Recommendations

i. A thorough investigation on the inter-seasonal rainfall variability, for both historical rainfall and future rainfall projections.

Historical climate trends for rainfall totals (both annual and seasonal totals) showed a decrease in rainfall. A thorough investigation on the inter-seasonal rainfall variability, for both historical rainfall and future rainfall projections, is recommended to enhance the understanding of rainfall patterns over the study area. Of particular interest to the farmers would be onset and cessation dates and wet and dry spell periods. This information is likely to inform better planning and adoption of appropriate farming practices for enhanced agricultural productivity. Researchers, with the facilitation of other stakeholders, should embark on this task as soon as possible to generate information that could inform successful farming practices over the study area in the face of a changing climate.

ii. Adoption of a localised and integrated climate change adaptation framework

Climate change adaptation at the study area was found to have realised minimal success in the past. A localised and integrated climate change adaptation framework generated in this study provides a pivotal launch pad from which effective adaptation options could be initiated. The framework brings together various actors and proposes a coordinated approach to effective climate change adaptation. This study recommends an adoption of this framework to help minimize the gap between policy and reality that was identified in the study area.

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APPENDICES

i. FGD questions template

Use of scientific and indigenous knowledge in adapting to climate change and variability in the Kenyan coast

FOCUS GROUP DISCUSSIONS (FGDs)

FGD questions

1. What is your perception or understanding on climate variability, and climate change?
2. What changes in your County would you attribute to Climate change and variability?
3. Many farmers in Kilifi County remark prolonged droughts and unpredictable and reduced rainfall as the most notable changes in climate. What are your thoughts on this? Is there any recorded data to support this? Are there any studies on climate change impact on the people?
4. What are your comments about the historical coping strategies used by farmers in Kilifi County against a changing climate? Which ones have worked and which have not?
5. How would you appraise efforts initiated by stakeholders in boosting the resilience of farmers against a changing climate, have they been successful?
6. As a stakeholder, have you been able to access climate information from anywhere? If yes, please state the source, type, ease of access and relevance of the said information. If not, please explain why.
7. What would you say are the best and sustainable adaptation strategies for your County in the face of a changing climate?
8. What should the stakeholders do to ensure effective adaptation against a changing climate?
9. Is there anything else you would like to say about your perception on climate and climate change, and the best way forward?

Introductory remarks

FGD Ground rules

WELCOME

Many thanks for being part of our FGD today. We appreciate your generous participation and look forward to a rewarding discussion.

INTRODUCTIONS

Moderator; assistant moderator

PURPOSE OF THE FGD

Mr. Obed Ogega, a master's student at the University of Nairobi, in conjunction with CORDIO East Africa is conducting a research on the 'Use of scientific and indigenous knowledge in adapting to climate change and variability in the Kenyan coast'. The research is embedded on MASMA project entitled 'Emerging knowledge for local adaptation'-implemented by CORDIO East Africa.

The purpose of this FGD is to merge indigenous knowledge with scientific knowledge in proposing appropriate and sustainable adaptation strategies against a changing climate in the Kenyan coast.

We would appreciate your open and objective input in the FGD.

GROUND RULES

1. We would like you to do the talking.
    - We would like everyone to participate.
    - I may call on you if I haven't heard from you in a while.
2. There are no right or wrong answers

- Every person's experiences and opinions are important.
- Speak up whether you agree or disagree.
- We would like to hear a wide range of opinions.

3. What is said in this room stays here
    - We want folks to feel comfortable sharing when sensitive issues come up.
4. The FGD will be recorded
    - We want to capture everything you have to say.
    - We don't identify anyone by name in our report. You will remain anonymous

Consent to Participate in Focus Group

You have been asked to participate in a focus group discussion (FGD) conducted by Mr. Obed Ogega, a Master's student at the University of Nairobi, in conjunction with CORDIO East Africa. The purpose of the FGD is to unfold the use of scientific and indigenous knowledge in adapting to climate change and variability in the Kenyan coast. The information generated from the FGD will be used to design appropriate and sustainable adaptation strategies for farmers in the Kenyan coast in the face of a changing climate.

You can choose whether or not to participate in the focus group discussion, and/or stop at any time. Although the FGD will be recorded, your responses will remain anonymous and no names will be mentioned in the report.

There are no right or wrong answers to the FGD questions. We would want to hear many various viewpoints, and from everyone. We hope you can be honest even when your responses may not be in agreement with the rest of the group. In respect for each other, we ask that only one individual speaks at a time in the FGD and that responses made by all participants be kept confidential.

By my signature here below, I (name in full) ____confirm having read and understood the information provided in this document, and agreeing to fully participate in the FGD under the conditions stated herein.

Participant's signature: ________________________________Date:__________________

ii. Semi-structured questionnaire

QUESTIONNAIRE/ORODHA YA MASWALI YA UCHUNGUZI

A) *IDENTIFICATION/KUJITAMBULISHA*

Name/Jina: ……………………………………………….Ward: ……………………………….
Telephone/nambari ya simu:………………………… LZ: ……………………………………
Enumerator/mwandikishaji:……………………………Date/tarehe:…………………..

B) *SOCIO-DEMOGRAPHIC FEATURES OF RESPONDENTS/MAELEZO YA KIJAMII YA WANAOJIBU*

#	QUESTIONS /*MASWALI*	ANSWERS /*MAJIBU*
1.	Gender of respondent /*Jinsia ya anayejibu*	01 = Male/*Mme* 02= Female/*Mke* [__][__]
2.	How old are you/ *Una umri upi?*	Record number of years/*Andikisha miaka yako* 99 = I don't know/*Sijui* [__][__]
3.	How long have you lived in this community / *Umeishi kwenye hii jamii kwa mda upi?*	Years/*Miaka* [__][__], months/*miezi* [__][__]
4.	What is the highest level of education that you have attained / *Kiwango chako cha juu zaidi cha elimu ni kipi?*	00 = None /*Hamna* 01 = Some primary education /*Sehemu tu ya shule ya msingi* 02 = Completed primary school/*Shule ya msingi* 03 = Secondary school/*Shule ya upili* 04 = College/*chuo* 05 = University/*Chuo kikuu* [__][__] 99 = Others/*Ingineyo* (Specify/*Fafanua*) ……………………………………………
5.	What is your marital status/*Hali yako ya ndoa ni ipi?*	01 = Married/*Nimeoa au Nimeolewa* 02 = Single/*kapera* [__][__] 03 = Divorced/separated *(Talikiwa/Nimetenganishwa)* 04 = Widow/*Mjane*, 98 = No answer/*Sijibu* 99 = Don't know/*Sijui*
6.	If married, number of spouses/ *Iwapo umeoa, una wake wangapi?*	Record exact number/*Andika idadi kamili* [__][__]
7.	Do you have any biological children/*Una watoto uliowazaa wewe?*	01 = Yes/*Ndio* 02 = No/*La* [__][__]
8.	If YES in question 11 above, indicate the number of children that you have/*Iwapo NDIO kwenye swali la 11, tupe idadi kamili*?	Record exact number/ *Andika idadi kamili* [__][__]
9.	How many of your children are in school/*Ni wangapi kati ya watoto wako wanaoenda shule?*	Record exact number/*Andika idadi kamili* [__][__]
10	Do you have any children in the school-going age but that are currently not going to school /*Una watoto walio na umri wa*	01 = Yes/*Ndio* 02 = No/*La*

	kwenda shule lakini ambao hawaendi shule?	[__][__]		
11	If YES above, please give your reasons why the children don't go to school/*Iwapo NDIO, tupe sababu ya watoto hawa kutoenda shuleni*	01 = Lack of/inadequate schools/*Ukosefu/Upungufu wa shule* 02 = Lack of school fees /*Ukosefu wa karo* 03 = Refused to go to school/*Walikataa kwenda shule* 04 = Early marriage/ *Waliolewa mapema* [__][__] 99 = Other/*Nyingineyo* (Specify/*fafanua*) ………………………………………………		
12	In addition to your children, how many people do you support in your household/ *Zaidi ya watoto wako wa kuzaa, ni watu wangapi walio chini ya wajibu wako nyumbani*?	01= None/*Hamna* 02= one to three/Mmoja hadi watatu 03= four and more/Zaidi ya wanne [__][__]		
13	What is your main source of livelihood/ *Chanzo kikuu cha riziki yako ni ipi? (Only one answer required/Inaruhusiwa jibu moja tu)*	00 = None/*Hamna*, 01 = Crop farming/*Ukulima wa mimea* 02 = Business/*Biashara*, 03 = Pastoralism/Ufugaji mifugo, 04 = Salary/Ajira 05 = Remittance/Msaada toka kwa jamaa na marafiki 06= Fishing /Uvuvi, 99 = Other/Nyinyineyo (Specify/Fafanua) [__][__] ………………………………………………		
14	What type of housing do you have/*Unaishi kwenye makaazi yapi?*	01 = Mud house with grass thatched roof/*Nyumba ya udongo ilo na paa la nyasi* 02 = Semi permanent (with iron sheet roof/*yenye paa la mabati*) 03 = Permanent/*Nyumba ya kudumu* (stone-walled/*nyufa za mawe*) 99 = Other/*Nyinyineyo* (Specify/*Fafanua*) [__][__] ………………………………………………		
15	Do you have access to electricity/*Umeunganishiwa umeme*?	01 = Yes/*Ndio*, 02 = No/*La* [__][__]		
16	What fuel do you use for cooking/*Unatumia nini kwa kupika?*	01 = Charcoal/*Makaa*, 02 = Firewood/*Kuni* 03 = Kerosene/*Mafuta taa* 04 = Residues/*Mabaki*, (specify/*fafanua*) 99 = Other/*Nyinyineyo* (specify/*fafanua*) [__][__] ………………………………………………		
17	Do you belong to any social networks (chamas, church, mosque, etc)/ *Una uanachama kwenye vikundi vyovyote vya kijamii (chama, kanisa, mskiti, na kadhalika)?*	01 = Yes/*Ndio*, 02 = No/*La* [__][__]		
18	If yes, give a list of groups to which you belong/ *Iwapo NDIO, orodhesha vikundi hivyo*			

	C) *LAND OWNERSHIP AND UTILIZATION/UMILIKI NA MATUMIZI YA SHAMBA*			
19	What is the approximate size of your land/*Kadri ya kiwango cha shamba lako ni ipi*?	00 = None/*Hamna* 01= Less than 1 acre/*Chini ya ekari 1*, 02= 1 – 3 acres/*Ekari 1 – 3*, 03 = 4 – 5 acres/*Ekari 4-5*, 04 = 6 – 10 acres/ *Ekari 6-10* 05 = More than 10 acres/ *Zaidi ya ekari 10* 99 = Don't know/ *Sijui* [__][__]		
20	What proportion of your land is under crop cultivation/*Ni sehemu ipi ya shamba yako iliyo chini ya upanzi wa mimea?*	Record actual area in acres / *Andika idadi kamili* [__][__]		
21	What proportion of your land is under pasture/ *Ni sehemu ipi ya shamba yako iliyo chini ya upanzi wa chakula cha mifugo?*	Record actual area in acres [__][__] *Andika idadi kamili*		
22	What proportion of your land is under tree cover/ *Ni sehemu ipi ya shamba yako iliyo chini ya upanzi wa miti?*	Record actual area in acres [__][__] *Andika idadi kamili*		
23	What food crop varieties do you grow/ *Ni aina gani ya vyakula unavyokuza?*	01= Maize/*Mahindi* 02= Millet/*Mtama* 03= Beans/*Maharagwe* 04 = Cassava/*Mihogo* 05=Cow-peas/*Kunde*, 99 = Other/*Vinginevyo* (Specify/*fafanua*) [__][__] ……………………………………………		
24	What is the location of your land/*Shamba lako linapatikana wapi*?	01= Uplands/slopes *Nyanda za juu/miteremko* 02= Lowlands/ *Nyanda za chini* 03= Plains/ *Sehemu tambarare* 04 = River valley/ *Bonde la mto* [__][__]		
25	Farmer's own perception of the fertility level of his land/*Tathmini binafsi ya mkulima kuhusu rutuba ya udongo wa shamba lake*	01= Infertile/*Uso rutuba* 02= Fertile/*Wenye rutuba* 03= Very fertile/*Wenye rutuba zaidi* 04 = Don't know/*Sijui* [__][__]		
26	For how long have you been farming/*Umekuwa ukifanya ukulima kwa mda upi*?	01= Less than 5 years, *Chini ya miaka 5* 02= 6 – 10 years, *Miaka 6-10*, 03= 11 – 20 years, *Miaka 11-20* [__][__] 04 = More than 20 years, *Zaidi ya miaka 20*		
27	What is your land's ownership/*Umilki wa shamba lako ni upi*?	01= Private property with title deed/*Wa kibinafsi ulo na cheti cha kumiliki shamba* 02= Communal land/ *Shamba la kijamii* 03= Ancestral land/*Urithi* (without title/*bila cheti cha kumiliki shamba*) 04 = Leasehold/*Kukodisha* [__][__] 99 = Other/*Nyingineyo* (Specify/*fafanua*) ………………………………………………..		
28	Who decides on the management of your land/*Ni nani aliye na uamuzi kuhusu usimamizi wa shamba lako?*	01= Head of household/*Mkubwa wa kaya* 02= Entire family/*Familia nzima* [__][__]		

		99 = Other/*Nyingineyo* (Specify/*fafanua*) ………………………………………………		
29	How far is the market from your farm/*Soko liko umbali upi kutoka kwa shamba lako*?	01= Less than 1 km, *Chini ya Kilomita 1,* 02= 1 – 10 km, *Kilomita 1-10,* [__][__] 03 = More than 10 Km, *Zaidi ya Kilomita 10*		
30	Do you have access to any agricultural extension services /*Unafikia huduma zozote za ugani?*	01 = Yes/*Ndio*, 02 = Yes/*La* [__][__]		
31	If YES above, from where do you get the extension services/ *Iwapo NDIO, huduma hizi unazipata wapi*?	01= Government/*Serikali*, 02= Private/ *Mashirika binafsi*, 03 = NGOs/ *Mashirika yasiyokuwa yakiserikali* 99 = Other/ *Nyingineyo* (Specify/*fafanua*) [__][__] ………………………………………………		
32	What is the frequency of the extension services/*Huduma hizi za ugani unazipokea kwa takriban mara ngapi?*	01= Weekly/*Kila wiki*, 02= Monthly/*Kila mwezi* 99 = Other/*Nyingineyo* (Specify/*fafanua*) [__][__] …………………………………………		
33	What is your average monthly household income from employment/*Idadi yenu (kaya) ya wastani ya riziki kutoka kwa ajira ni ipi?*	00= Nil/*Hamna*, 01= Less than/*Chini ya* KES 10,000 02= 10,000 – 30,000 KES, 03 = 30,000 – 50,000 KES 04 = Over/*Zaidi ya* 50,000 KES [__][__]		
	D) *FOOD SECURITY/UTOSHELESHAJI WA CHAKULA*			
34	Does your household experience shortage of main food items/*Kaya lako hukabiliwa na upungufu wa vyakula kuu?*	01 = Yes/*Ndio*, 02 = No/*La* [__][__]		
35	If YES, how many food deficient months do you experience in a year/*Iwapo NDIO, ni kwa takriban miezi mingapi kunapokuwa na upungufu?*	01= Less than 3 months/*Chini ya miezi mitatu,* 02= 4 -5 months/*Miezi,* 03 = Over 5 months/*Zaidi ya miezi mitano* [__][__]		
36	If YES, what are the reasons for food shortages experienced/ *Iwapo NDIO, ni zipi sababu zako zinazopelekea upungufu huu?* (Multiple responses are acceptable /*Majibu mengi yanaruhusiwa*)	01= Drought/*Kiangazi*, 02= Floods/ *Mafuriko* 03= Lack of farm inputs/ *Ukosefu wa pembejeo za kilimo* 04 = Insufficient/unproductive land/ *Upungufu wa shamba/shamba lisilo na faida* 99 = Other/*Nyingineyo* (Specify/*fafanua*) [__][__] ………………………………………………..		
37	If YES, how do you cope with the food shortage/*Iwapo NDIO, ni vipi unavyokabiliana na upungufu huu?*	01= Buy food/*Ununuzi wa chakula* 02= Seek assistance from relatives, neighbors and friends /*Msaada kutoka kwa jamaa, jirani na marafiki* 03= Beg food relief from government/ *Kutegemea msaada kutoka kwa serikali* 99 = Other/ *Nyingineyo* (Specify/*fafanua*) …………………………………… [__][__]		

38	How many meals do you have in a day/*Huwa una milo ngapu kwa siku?*	01= One/*Moja*, 02= Two/*Miwili*, 03=Three/*Tatu* [__][__]		
39	If YES, why/*iwapo NDIO, kwa nini?*	01= Personal choice/*Uamuzi wa kibinafsi* 02= Inadequate food/ *Upungufu wa chakula* 03= Others/ *Nyingineyo* (Specify, *fafanua*) ……………………………….. [__][__]		
	E) *CLIMATE CHANGE AND VARIABILITY/MABADILIKO YA TABIA NCHI YA MUDA MFUPI NA MUDA MREFU*			
40	What significant changes in weather have you experienced in your area over the last 30 years/*Ni mabadiliko yapi makubwa ya hali ya anga uliyoyashuhudia katika sehemu unayoishi kwa muda wa miaka 30 iliyopita?*	01= Unpredictable rains/*Mvua isiyotabirika* 02= Prolonged drought/ *Mafuriko yazidiyo muda wa kawaida* 03= Very hot seasons/*Nyakati zenye joto jingi* 04 = Very wet seasons/*Nyakati zenye mvua nyingi,* 05 = Don't know/*Sijui* 99 = Other/*Nyingineyo* (Specify/*fafanua*) ………………………………………… [__][__]		
41	In your opinion, what has happened to the number of hot days over the last 30 years/*Kwa maoni yako, nyakati za joto zimekuwaje kwa muda wa miaka 30 iliyopita?*	01= Increased/*Zimeongezeka*, 02= Declined/*Zimepungua* 03= More extreme/*Zimekuwa kali zaidi* 04 = Less extreme/*Zimepunguza makali* [__][__]		
42	In your opinion, what has happened to the number of rainfall days over the last 30 years/*Kwa maoni yako, nyakati za mvua zimekuwaje kwa muda wa miaka 30 iliyopita?*	01= Increased/*Zimeongezeka*, 02= Declined/*Zimepungua* 03= Change in timing of the rains/*mabadiliko ya nyakati za mvua* 04 = Decrease in rains and change in timing/*kupungua kwa mvua na kubadilika kwa nyakati za kunyesha* 05 = Change in frequency of droughts or floods/*madadiliko ya marudio ya kiangazi au mafuriko* [__][__]		
43	What is the main impact of these weather changes on the local community/*Madhara makuu ya mabadiliko haya ya hali ya hewa kwenye jamii ni yapi?*	01= Crop failure/ *kutostawi kwa mimea* 02= Flooding /*mafuriko* 03= Human disease outbreaks/*mkupuruko wa magonjwa ya binadamu* 04 = Livestock disease outbreak/*mkupuruko wa magonjwa ya mifugo* 05 = Increased production/*mazao yaliyoimarika* 06 = Migration to other places/*kuhamia sehemu zingine* 97 = Don't know/*sijui* [__][__] 99 = Other/*nyingineyo* (Specify/*fafanua*) ………………………………………………..		
44	Have you made any adjustment in your farming practices to climate change and variability/*umefanya mabadiliko yoyote*	01 = Yes/*Ndio*, 02 = No/*La*		

	shambani ili kuyakabili mabadiliko ya tabia nchi?	[__][__]		
45	If yes, what adjustments have you made in your farming practices to these long-term shifts in temperature and rainfall/*iwapo NDIO, ni mabadiliko yapi umefanya katika ukulima wako dhidi ya mabadiliko haya ya kudumu ya nyuzi joto na mvua?* Tick the adjustments made/*Chagua majibu baina ya yafuatayo* (Multiple responses allowed/*majibu mengi yanakubaliwa*)	01 = Change in crop variety/*kubadilisha aina ya mimea*		
		02 = Build water harvesting schemes/ mbinu za kuvuna maji		
		03= Implement soil conservation schemes/kutumia mbinu za kuhifanyi mchanga		
		04= Diversification of crop types and varieties/*utumiaji wa mimea tofauti na aina nyinyi ya mimea fulani*		
		05 = Diversification of livestock types and varieties/ *ufugaji wa mifugo tofauti na aina nyinyi ya mimea fulani*		
		06 = Changing planting dates/*kubadilisha tarehe za kupanda*		
		07 = changing size of land under cultivation/ *kubadilisha kiwango cha ardhi kinacholimwa*		
		08= Irrigation/*unyunyizaji maji*		
		09 = Reduce number of livestock/*Kupunguza idadi ya mifugo*		
		10 = Diversification from farming to non-farming activities/ *kuacha ukulima na kufanya mambo mengine*		
		11= Use of fertilizer/manure/ *kutumia mbolea*		
		99 = Other/*Mengineyo* (Specify/*Fafanua*)		
46	Do you have insurance for your crops/livestock / Una bima ya mimea/mifugo yako?	01 = Yes/*Ndio*, 02 = No/*La* [__][__]		
47	If YES, what insurance services do you have/*Iwapo NDIO, ni huduma zipi hizo*? Please list them/*tafadhali ziorodheshe*			
48	If NO, please explain why not/ *iwapo LA, elezea kwa nini hauna huduma hizo.*	01= Lack of capital/*ukosefu wa raslimali* 02= Lack of information about insurance/*ukosefu wa habari kuhusu bima* 03 = Lack of insurance services in my area/*ukosefu wa huduma za bima katika sehemu yangu* 99 = Other/ *Nyinginezo* (Specify/*fafanua*) [__][__] …………………………………………………………..		
49	Do you have any constraints to adaptation efforts against the impacts of climate change/*Una changamoto zozote katika kukabiliana kwako na madhara ya mabadiliko ya tabia nchi?*	01 = Yes/*Ndio*, 02 = No/*La* [__][__]		
50	If YES, list the main constraints to adaptation measures/*Iwapo ndio, orodhesha changamoto hizo*	01= Lack of capital/*ukosefu wa raslimali* 02= Lack of information/*ukosefu wa habari* 03= Shortage of labour/*ukosefu wa wafanyakazi* 04 = Lack of access to water/*ukosefu wa maji* 05 = Poor health/*afya mbaya* [__][__] 99 = Other/ *Nyinginezo* (Specify/*fafanua*) ………………………………………………..		

51	Are there any institutions /organizations in your community with which your community has worked in addressing the impacts of climate change on livelihoods/*Kuna taasisi / mashirika yoyote kwenye jamii yako ambayo yanakabiliana na madhara ya mabadiliko ya tabia nchi kwenye riziki?*	01 = Yes/*Ndio*, 02 = No/*La* [__][__]		
52	If YES, please indicate what type of institutions/organizations they were/ *iwapo NDIO, elezea ni aina ya taasisi/mashirika hayo*	01= National Government/*serikali kuu* 02 = County Government/*Serikali ya Gatuzi* 03= Private sector organizations/ *mashirika ya kibinafsi* 04 = NGOs /*Mashirika yasiyokuwa ya kitaifa* 05 = Individuals of good will/*Wahisani* 99 = Other/*Nyingineyo* (Specify/*Fafanua*) [__][__] ……………………………………………		
53	If YES, please indicate what help you got from the institutions /organizations/ *Iwapo NDIO, fafanua ni msaada gani ulipata kutoka kwa taasisi/mashirika hayo*			
54	If YES, has the intervention of these organizations been helpful/*Iwapo NDIO, msaada huu umekuwa wa manufaa?*	01 = Yes/*Ndio*, 02 = No/*La*, 99= Don't know/*sijui* [__][__]		
55	Have you received any interventions from the County Government to help you adapt to the impacts of climate change/*Umepokea msaada wowoke kutoka kwa serikali ya Gatuzi lako ili kukusaidia kukabiliana na mabadiliko ya tabia nchi?*	01 = Yes/*Ndio*, 02 = No/*La*, 99= Don't know/*sijui* [__][__]		
56	If YES, please list the interventions/ *Iwapo NDIO, tafadhali ziorodheshe huduma hizi*			
57	What interventions would you like the County Government to do to help you enhance your farming? Please list them/*Ni hatua zipi ambazo ungependa serikali ya Gatuzi ichukue ili kukuwezesha kuimarisha ukulima wako? Tafadhali ziorodheshe.*			
THANK YOU FOR YOUR COOPERATION/ASANTE KWA MUDA WAKO				

Adopted from Oremo (2013)

CONSENT FORM

Dear Sir/Madam,

My name is OGEGA, OBED MATUNDURA; a graduate student of Climate Change Adaptation (Master's) at the Institute for Climate Change and Adaptation (ICCA), University of Nairobi.

Together with CORDIO East Africa, I’m carrying out a research on the use of scientific and indigenous knowledge in adapting to the impacts of climate change and variability in the Kenyan coast. Your responses in my questionnaire will be vital in helping me realize the objectives of the study.

This information is being collected solely for academic purposes, and there are no personal benefits or risks to your participation. Some of the questions asked in the questionnaire may be of sensitive to you. However, I guarantee that your personal identifier information (PII) shall be kept confidential. The interview will take approximately 30 minutes or less; depending on your cooperation.

For more information about this study, please contact the researcher on ..., or email...

May I have your permission to undertake this interview?

If YES, kindly fill in the following details:

Name: ____

Signature: ______________________________

Date: _________________________________

iii. Summarized FGD report

FGD ITEM	RESPONSES FROM KILIFI	RESPONSES FROM KWALE	COMBINED RESPONSES
Perception on climate change and variability (CVC)	All the participants said that they perceived climate change as real, and that they had experienced it in one form or another	General perception on climate change and variability was that it is real, and being experienced in Kwale County.	The common consensus was that Climate change and variability was real and being experienced at the Kenyan coast.
Observed changes attributed to CVC	• Crop failure • Emergency and re-emergency of pests and diseases	• Reduced rainfall, and change in rainfall patterns • increased temperature	• Crop failure • Emergency and re-emergency of pests and diseases • Reduced rainfall, and change in rainfall patterns • increased temperature • Increased charcoal production for income due to reduced livelihood options
Identification of prolonged droughts and unpredictable and reduced rainfall as the most notable changes in climate in respective Counties.	All participants agreed with the findings of the survey. NDMA and KACCAL said records/statistics, consistent with these observations, were available	Participants said that the information generated from Kilifi County was representative of the situation in Kwale County too. Trend analysis for Kwale's climatology showed negative trends in terms of rainfall. This was consistent with the farmers' perception of the climate in Kwale.	The FGDs confirmed the findings of the questionnaire survey. Technical Institutions such as NDMA and KACCAL confirmed the availability of scientific records/statistics that were consistent to the observations made by farmers
Comments on historical coping strategies used, which ones have worked and which ones have not	• Participants thought the coping strategies were good but ought to be practised properly and in sufficient scale so as to realize significant results • The indigenous way of consulting more experienced farmers/elders on farming issues was lauded as a good practice/measure	• Participants remarked that the coping strategies used by farmers in Kilifi County were similar to those used in Kwale County • They argued that though the strategies were good, there was relatively low uptake of modern adaptation practices. Hence, more needed to be done to ensure that the said	Participants thought the coping strategies were good but ought to be practised properly and in sufficient scale so as to realize significant results. Some of the modern coping strategies that were being used by some farmers include diversification in crop types such as from maize to cassava farming. Some farmers had also diversified crop varieties as advised by actors such as the

	• Diversification in types of crops (e.g. from maize to cassava) was identified as one of the successful adaptation strategies • Bad eating habits and retrogressive traditional beliefs and practices were said to be frustrating some adaptation efforts.	adaptation strategies were more effective. • Traditionally, farmers used to practice organic farming. Today, farmers are gradually shifting to the indigenous methods of farming (such as organic farming, closed farming, multicropping, and mixed farming) • Farmers in Kwale have a tradition of clearing of their farmland through burning was said to be highly practiced. Farmers ought to be sensitized against this practice	Department of Agriculture in the Counties involved. Some of the indigenous knowledge/strategies that were used in farming include: * Observing behaviour of birds such as presence of migratory birds and presence of a particular birds flying high in the air. Birds flying high in the sky imply good weather, while those seated on mangroves would signify bad weather * Presence of specific fish species was also used to inform weather prediction. For instance, presence of lobster, octopus, etc, in the fishermen's basket traps would indicate bad weather ahead *presence of butterflies * Arrangement of stars in the sky would also be used to indicate the coming weather *Appearance of Rainbows was said to indicate an ending rains season *Swaying of leaves on a coconut trees would indicate the coming of rains
An appraisal efforts initiated by stakeholders in boosting the resilience of farmers against a changing climate	Successful efforts: promotion of diversification in crop types (e.g. from maize to cassava, cowpeas and cashew nuts)	• Sporadic organic farming and adoption of modern farming practices • Diversification from traditionally grown food crops (such as maize) to new crops such as cassava and passion fruits. • Increased awareness on climate-smart agriculture	Some adaptation efforts against a changing climate at the Kenyan coast were said to be bearing fruits. Such efforts include: • Sporadic organic farming and adoption of modern farming practices • Diversification from traditionally grown food crops (such as maize) to new crops such as cassava and passion fruits. • Increased awareness on climate-smart agriculture

	Failed efforts: • Seed variety given by County Government. E.g. PH1 not doing well, and inadequate • Tractors for ploughing. Increased acreage, no rains or irrigation? • Duplication of efforts – interventions not well coordinated • Provision of demand-driven extension services not working well because of inadequate extension officers, and poor facilitation.	• Change in crop varieties and diversification efforts had not been very successful. Some initiatives were introduced, but not followed through to completion. • Some modes of information dissemination (such as radio) were said not to be reaching some segments of the population such as the youth. Call for more efficient means of information dissemination • Some services such as soil analysis and purchase of certified seeds were said to be too expensive for some farmers. There was need to provide such services at a more affordable cost to enable access to as many farmers as possible. • While innovative farming practices were being promoted, some segments of the population did not appreciate agriculture. Some people in Kwale thought that farming was meant for failures, and could not be a source of a descent employment. • Sinking of boreholes for irrigation was said not to be well coordinated. As a result, there was a risk of sea water intrusion.	Some adaptation efforts that were being implemented by some actors were said not to be very successful. Some of the non-very-successful efforts include: • Seed variety given by County Government. E.g. PH1 not doing well, and inadequate • Tractors for ploughing. Increased acreage, no rains or irrigation? • Duplication of efforts – interventions not well coordinated • Provision of demand-driven extension services not working well because of inadequate extension officers, and poor facilitation. • Change in crop varieties and diversification efforts had not been very successful. Some initiatives were introduced, but not followed through to completion. • Some modes of information dissemination (such as radio) were said not to be reaching some segments of the population such as the youth. Call for more efficient means of information dissemination • Some services such as soil analysis and purchase of certified seeds were said to be too expensive for some farmers. There was need to provide such services at a more affordable cost to enable access to as many farmers as possible. • While innovative farming practices were being promoted, some segments of the population did not appreciate agriculture. Some

		The drying up of wetlands around the area of Mrima in Kwale county was attributed to uncontrolled sinking of boreholes around that area.	people in Kwale thought that farming was meant for failures, and could not be a source of a descent employment. • Sinking of boreholes for irrigation was said not to be well coordinated. As a result, there was a risk of sea water intrusion. The drying up of wetlands around the area of Mrima in Kwale county was attributed to uncontrolled sinking of boreholes around that area.
Access to climate information: source, type, ease of access and relevance of the information accessed	Participants remarked that some climate information was available out there	The climate information available was said to be scanty	Farmers indicated that they were able to access some form of climate/weather related information. However, the information was said to be scanty and unreliable.
	Sources of information included outreach programs, extension services, farmer field schools, and the internet. Organizations that provided this information included the Kenya Meteorological Department (KMD), Kenya Youth Climate Network and Universities such as Pwani University	KMD, ASDSP and NDMA among other government departments.	Sources of information included outreach programs done by various actors (such as Pwani University), extension services provided by both the National and County governments, farmer field schools, and the internet. Organizations that provided this information included the Kenya Meteorological Department (KMD), Kenya Youth Climate Network and Universities such as Pwani University
	Type of information accessible was on best farming practices		

	Ease of access - some government departments were difficult to access for information. Most departments were not adequately equipped with resources to provide services to the farmers. For instance, some departments had only one officer expected to cover the entire County.	Few agriculture extension officers were available, but they were not able to (effectively and in a timely manner) cover the entire County. There was concern about the desire of the people of Kwale to seek climate information to inform their farming. It was remarked that many people over-relied on relief food, and were not keen on venturing into farming despite having adequate productive land, some incentives and good weather. Many farmers would also want to be paid to participate in meetings/workshops that are meant to help them in their farming. This made it difficult for outreach/fieldwork activities to prosper	Few agriculture extension officers were available, but they were not able to (effectively and in a timely manner) cover the entire County. There was concern about the desire of the people of Kwale to seek climate information to inform their farming. It was remarked that many people over-relied on relief food, and were not keen on venturing into farming despite having adequate productive land, some incentives and good weather. Many farmers would also want to be paid to participate in meetings/workshops that are meant to help them in their farming. This made it difficult for outreach/fieldwork activities to prosper
	Relevance - participants regarded the information accessed to be relevant in many cases, but urged stakeholders to increase the penetration of information so as to reach as many farmers as possible		The FGDs deduced that the climate/weather/agriculture related information accessed was fairly relevant in many cases, but urged stakeholders to increase the penetration of the information so as to reach as many farmers as possible

Proposed appropriate and sustainable adaptation strategies	• A comprehensive adaptation framework factoring all aspects of adaptation • Increased and more effective irrigation • Organic farming and agro-forestry • Conservation agriculture • Diversification of crop varieties and types	• A comprehensive adaptation framework for Kwale County to ensure that interventions are not left 'half-pregnant'. E.g. teaching and demonstrations are done but there's no follow-up to ensure implementation/uptake for famers • Diversification of crops, and crop varieties. Need to focus on drought tolerant crops for various AEZs.	The FGDs deemed the following adaption strategies to be appropriate and sustainable for farmers at the Kenyan coast: • A comprehensive adaptation framework for Kwale County to ensure that interventions are not left 'half-pregnant'. E.g. teaching and demonstrations are done but there's no follow-up to ensure implementation/uptake for famers • Increased and more effective irrigation • Organic farming and agro-forestry • Conservation agriculture • Diversification of crops, and crop varieties. Need to focus on drought tolerant crops for various AEZs.

What should be done to ensure effective adaptation against a changing climate	• Better coordinated interventions aimed at helping farmers adapt to cc • Logistics – affordable and economically viable inputs for the farmers. • Need for more robust land management policies • Creation of new markets that have the interests of farmers at heart • Sensitization against retrogressive eating habits. To discourage overreliance on maize, and promote adoption of other food crop varieties such as cassava • Increased civic education and awareness promoting climate smart agriculture • Promotion of sustainable farming practices suitable for various AEZ • More and improved support on irrigation e.g. underground water tanks at schools, enhanced water harvesting, and tapping seasonal rivers • Robust and sustainable agro-forestry initiatives. Growing select tree species for different areas, e.g. mangroves, coconut trees, etc	• Increased access to water for irrigation to reduce reliance on rainfall for farming • Perception change in farmers' approach to farming. Need to embrace new and innovative farming technologies and practices. E.g. preservation of surplus produce for future use • Robust land ownership and utilization policy formulation and implementation • A better coordinated approach to interventions by all actors to avoid duplication of efforts • Use of more inclusive/diverse tools of information dissemination	To enable the proposed adaptation strategies to work, the following actions were identified to be of utmost importance: • Better coordinated interventions aimed at helping farmers adapt to cc • Logistics – affordable and economically viable inputs for the farmers. • Need for more robust land management policies • Creation of new markets that have the interests of farmers at heart • Sensitization against retrogressive eating habits. To discourage overreliance on maize, and promote adoption of other food crop varieties such as cassava • Increased civic education and awareness promoting climate smart agriculture • Promotion of sustainable farming practices suitable for various AEZ • More and improved support on irrigation e.g. underground water tanks at schools, enhanced water harvesting, and tapping seasonal rivers • Robust and sustainable agro-forestry initiatives. Growing select tree species for different areas, e.g. mangroves, coconut trees, etc • Formulation and implementation of wetland protection policies. Restrict farming along rivers and ocean so as to reduce risks related to flooding and erosion • Enhanced research on drought tolerant crop varieties

	• Formulation and implementation of wetland protection policies. Restrict farming along rivers and ocean so as to reduce risks related to flooding and erosion • Enhanced research on drought tolerant crop varieties • Enhanced value addition services for better returns for farmers • Sensitization against retrogressive traditional practices such as witchcraft that hamper farming • Education on alternative and less popular livelihood options such as planting chillies • Reduction of charcoal production using trees, by promoting alternative techs such as briquettes.		• Enhanced value addition services for better returns for farmers • Sensitization against retrogressive traditional practices such as witchcraft that hamper farming • Education on alternative and less popular livelihood options such as planting chillies • Reduction of charcoal production using trees, by promoting alternative techs such as briquettes. • A better coordinated approach to interventions by all actors to avoid duplication of efforts • Use of more inclusive/diverse tools of information dissemination