# SPATIO-TEMPORAL CLIMATE CHANGE AND ITS EFFECTS ON HOUSEHOLD LIVELIHOODS IN THE LAKE VICTORIA BASIN OF KENYA

BY
EVANS ODHIAMBO WABWIRE
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# DECLARATION

I declare that this research is my original work and has not been submitted for examination or award of degree in any other institution of higher learning. Other people's work used in this research has been properly acknowledged and referenced in accordance with the University of Nairobi requirements.

July 6th , 2021

Date

Evans Odhiambo Wabwire
(C80/50967/2016)

This PhD Thesis has been submitted for Examination with our approval as university supervisors.

Dr. Isaiah Ang'iro Nyandega
Department of Geography and Environmental Studies
University of Nairobi

Dr. Mikalitsa S. Mukhovi
Department of Geography and Environmental Studies University of Nairobi

# DEDICATION

To my Children; Cleon Peter, Kimberly Kathleen and Yannick Evan.

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# LIST OF ACRONYMS AND ABBREVIATIONS

| | |
|---|---|
| ANOVA | Analysis of Variance |
| CORDEX | Coordinated Regional Climate Downscaling Experiment |
| CMIP5 | Coupled Model Inter-comparison Project |
| CHIRPS | Climate Hazards Group Infrared Precipitation with Station Data |
| CRU | Climate Research Unit |
| DJF | December January February |
| $ET_o$ | Evapotranspiration |
| ENSO | El-Nino Southern Oscillation |
| FAO | Food and Agricultural Organization |
| GHGs | Green House Gases |
| GPCC | Global Precipitation Climatology Center |
| GPCP | Global Precipitation Climatology Project |
| GCM | Global Climate Model |
| HEP | Hydro Electric Power |
| ICT | Information Computer Technology |
| ITCZ | Inter-Tropical Convergence Zone |
| IPCC | Intergovernmental Panel on Climate Change |
| JJAS | June July August September |
| MAM | March April May |
| RCM | Regional Climate Model |
| SPSS | Statistical Package for Social Sciences |
| SON | September October November |
| SoK | Survey of Kenya |
| TRMM | Tropical Rainfall Measuring Mission |
| UNFCC | United Nations Framework Convention on Climate Change |
| UNEP | United Nations Environmental Programme |
| WHO | World Health Organization |
| WMO | World Meteorological Organization |

# ABSTRACT

The general public view is that changes in climate are indeed occurring globally. Recent studies have established an unprecedent variations in climate change events with the Lake Victoria Basin of Kenya, which are attributed to climate change. This study sought to determine the climate change and its effects on rural household livelihoods in the Lake Victoria Basin of Kenya. The study guided by the following objectives: to assess the spatial and temporal variations in the Lake Victoria Basin of Kenya using rainfall and temperature indices, to analyze the effects of the current climate change on rural household livelihood in the Basin, to establish climate change adaptation strategies employed by the rural household in the Lake Victoria Basin of Kenya and, to determine the future climate change scenarios over the Lake Victoria Basin of Kenya. The hypotheses for this study were: the rainfall and temperature indices over the Lake Victoria Basin of Kenya have not significantly varied, the rural household livelihoods in the Lake Victoria Basin of Kenya have not been significantly affected by changes in climate, the rural households over the Lake Victoria Basin of Kenya have not employed significant adaptation strategies that address their livelihoods and, the future climate scenarios over the Lake Victoria Basin of Kenya do not vary from the present climate scenario. A multi-stage sample survey research design consisting quantitative and qualitative approach was adopted for this study. Both secondary and primary data, for climate and household data respectively, were used to achieve the objectives. The climate data were sourced from 14 weather and gridded data stations while, household data were sourced from 359 households sourced from a field sample survey using a multi-stage stratified random sampling technique. The datasets were subjected to various statistical analysis techniques preceded by quality control and homogeneity test. Climate data was subjected to time series analysis to determine climate trends, seasonality and hydrologic characteristic in the Lake Victoria Basin of Kenya. On the other hand, the household data was subjected to both basic and inferential statistical analysis that included logistic regression model analysis using statistical tools available in SPSS IBM 21. The study revealed a decline in the normal wetness conditions due to increased episodes of extreme low rainfall events. Furthermore, the long rains, Mar-May seasonal rains, have declined while short rains, Oct-Dec seasonal rains, have increased. The number of rainy days has also declined in the both rainy seasons. The means of minimum and maximum temperatures have significantly increased between 0.5ºC - 0.7ºC and 0.7ºC and 1ºC in the basin's highlands and lowlands respectively. The models project a declining trend for both long and short seasonal rainfall. A decrease in both long (Mar-May) and short (Oct-Dec) rains are projected under low (RCP4.5) and high (RCP 8.5) emission scenario. The rainfall onsets and cessations are also projected to vary significantly in both the near and far future. The climate change effects that affected the rural livelihoods emanated mainly from frequent and prolonged severe droughts which resulted into a decline in subsistence production, increased water stress, increased cases of human and crop disease, low fish count and, damage to household properties. The result further revealed that majority of households adopted short term mechanisms to cope with climate change. The study recommends a need for the policy makers to address emerging extreme climate events through a policy framework. The study also recommends a comprehensive climate change action plan at national, county, and local levels which is more focused on rural households. Climate-Smart Agriculture and Integrated Water Use and Management are among the projects recommended for the Lake Victoria Basin of Kenya.

# CHAPTER ONE

## 1.0 INTRODUCTION

### 1.1 Background of the Study

Changes in climate have always occurred throughout historical time. The current changes however, are one of the most demanding and intricate issues the contintent is grappling with today. The climate change realities are now being manifested in the increased episodes of unpredictable extreme weather events. Heavy human casualties, accompanied by huge losses economically as a result of extreme weather conditions have been recorded internationally (Eckestein, 2019). Further risks associated with extreme climate events are projected, especially due to an increase as the global mean temperature rises (IPCC 2014). While anthropogenic activities have been blamed for an increased emission of greenhouse gases that triggers extreme climate event, recent studies show that changes in land use significantly contributes to global temperature increase (IPCC, 2013). Since 2014, a record high temperatures have continued to be documented (Power, S. B., & Delage, F. P.,2019), with even more increasing trends being projected in the future under increased emissions scenarios (ibid). Global threats of climate change certainly require urgent human attention on water resources, energy sources and use, food security, spread of pests and diseases (World Economic Forum (2015).

A brief tropical climate outlook shows that regions have experienced a significant temperature rise and rainfall variations which have had a direct influence to rural livelihood system (Berhe et al., 2017; Djoudi et al., 2016; FAO, 2008a and IPCC, 2007). The climate change effects can be observed across different continents; over the United States of America (hereafter referred to as the USA) for instance, a warming trend observed in the region has increased the frequency of cyclones (1991) and extreme heat events (Karl, 2009). The climate simulations further project an increase in extreme climate events in the future (IPCC, 2007). If such projections are anything to go by, then, we can certainly anticipate great danger to most vulnerable people especially the poor, the elderly, the children and, those with impaired health and limited mobility in the region.

The floods phenomenon has also been reported to be on the increase. For instance, a strong correlation was established between increased rainfall intensity recorded in some regions of the USA with flood events of 1993, 2008, 2011, 2013, and 2014 (O'Neil & Ebi, 2009). During the time which vector-borne diseases were also reported to be pronounced in the USA. Generally, floods in the USA have had adverse consequences for most families. The frequency of floods in USA resonates with an increased large-amplitude fluctuation of tropical cyclones due to increased Greenhouse Gases accumulation in the atmosphere (Knutson et al., 2010). The future projection of tropical cyclone indicates that changes in climate system will have an insignificant impact on its frequency and intensity once the saturation of change has reached the peak (Holland & Bruyère, 2014).

The changes in climate have not been any different in the Latin American region. IPCC report (2007), blamed climate change for decline in agricultural production and the displacement of agricultural activities from the tropical zone to higher latitude areas, which has lower temperatures (CEPAL, 2010). Similarly, the Caribbean Island has also observed increased precipitation recorded in the recent past causing frequent and persistent floods. The occurrence of floods in the Caribbean has resulted in deaths, destruction of crops, and prevalence of diseases to most households.

Over Europe, spatial variations of climate change have been observed, with recent projections showing an upward trend in temperature in the Arctic zone, resulting in increased loss of biodiversity (Kossida et al., 2012). In other zones, winter storms have increased, resulting in floods while other zones observed increased temperature and decreased precipitation. The variations in temperature and precipitation have increased the forest fire risk at the same time expanded the habitat for disease vectors (Coumou & Robinson, 2013). Climate plays an essential part in agricultural sector in Europe. For example, all the processes of grape farming are regulated by specific climatic requirements. However, fear exists owing to the extremes in climate variations (Kenny & Harrison, 1992), which have negatively affected farming to the limits. The unmitigated climate change and without solid adaptation measures put in place are likely to have a significant impact on its distribution and agricultural production in Europe.

Over Asia and the Pacific region, frequent tropical cyclones and prolonged dry spells that are accompanied by severe heatwaves have been documented (Cai et al. 2014). Such extreme climate events, coupled with natural disasters, are likely to pose further challenges to the already vulnerable communities, thus retrogressing concerted efforts of alleviating poverty and the achievement of sustainable livelihoods. To the poor farmers and rural communities, the changes in regional climate have caused a serious threat such as low agricultural activities (Liru, 2020).

Significant changes in climate have been observed across Africa (Dasio, 2017; IPCC, 2007; Herrero, 2010). The changes have manifested significant rainfall variations including the great horn of Africa (Anyah & Qiu 2012; Favre et al., 2011). The Sahel region for instance, recorded a temperature increase which accelerated drought events. The southern and western region of Africa have reported an increased number of warm spells and decreased numbers of extremely cold days between the years 1961 and 2000. Rainfall variations with spatial and temporal characteristics have also been reported over West Africa (Stansel, 2018; Barnett, 2003). An annual downward rainfall trend was observed in the region since the 1960s, while Southern Africa has observed an increased inter-annual rainfall variability culminating to more intense and widespread droughts experienced in the recent past. Changes in climate cannot therefore be underestimated in Africa considering, the fact that the majority of households rely on resources that are propelled by climates for their livelihoods.

A report by the Government of Kenya further revealed that most of its's economy and the natural ecosystems are climate-driven (GoK, 2010). The dependency on climate, therefore, makes the country highly vulnerable considering its large population in the region, which highly depends on rain-fed agriculture (Gebrechorkos et al., 2019; Amissah-Arthur, 2003; Cooper et al., 2016) for food and economic well-being. Climate variability is also linked to incidences of Malaria and Rift Valley fever which were reported to be on the increase and expanding to highland areas where few cases had earlier been reported (Tanser et al., 2003; UNFCC, 2007). Over the Lake Victoria Basin of Kenya, climate change-related events such as El Nino have been observed (ICPAC, 2007). However, the region has a low adaptive capacity (Hassan & Nhemachena 2008) and each household depends on climate-related resources (Neil et al., 2008) to meet its own basic needs for food, shelter, clothing, health, and education (Commission for Africa, 2005). If the recent climate projections within the Lake Victoria basin remain accurate (Ongoma et al., 2018; Omondi et al., 2009), then households are bound to be burdened more in meeting their needs. The degree of such burdens will certainly depend on the household's adaptation capability.

It is certain that in Africa climate has changed since the beginning of the twenty-first centuary (Low., 2006), and the effect of this change is negatively affecting the livelihoods of many households (Tadesse., 2010) thus it is important to undertake this study specifically on the Lake Victoria Basin of Kenya where the population are rapidly growing, poverty levels are rising, disease incidence (HIV/AIDS) is among the highest in the region ( Opio et al., 2013, Drimie et al., 2009) and climate change would devastate this already vulnerable region. It is against this background that this study sought to investigate the spatio-temporal climate change and its effects on household livelihoods in Lake Victoria Basin of Kenya.

## 1.2 Statement of Problem

This study addressed the following research questions regarding the Lake Victoria Basin of Kenya: first, what is the spatio-temporal climate variations over the Basin, using rainfall and temperature indices? Second, how is the current climate change affecting rural household livelihood in the Basin? Third, what climate change adaptation strategies are employed by rural households in the Basin? and fourth, what is the possible future climate change scenarios over the Basin. While several studies have attempted to address those questions (Broman et al., (2020)., Jury, M. R. (2013)., Gaughan, A. E., & Waylen, P. R. (2012)., Schreck III, C. J., & Semazzi, F. H. (2004)., Nicholson, S. E. (1996)), no specific study has investigated the spatial and temporal climate change over the Lake Victoria Basin of Kenya, using rainfall and temperature indices. Such studies therefore still remain limited and with various gaps that need to be further investigated. Further attempts have been done to understand the effects of on several sectors such as agriculture (Abdul and Kruse, 2017; Falco, C., Donzelli, F., & Olper, A., 2018; Dube et al., 2016), water resources (Dragoni and Sukhija 2008), and food security (Akudugu et al.,2012); little attempts has been done to link effects to rural household livelihoods with specific reference to the Lake Victoria Basin.

According to the World Bank Report, to attain sustainable human livelihoods, there is a need to understand the climate system which in this case is affected by many other physical factors, such as complex topography and presence of large water body. The role of Lake Victoria in modifying the climate of the basin is enormous. The spatial and temporal features of the basin's climate has been attributed to its complex landscape and the presence of Lake. The changes in climate in the basin have been erratic and unpredictable. Seasonal rainfall have decreased while, temperatures have increased (Ambeje, et al., 2011; Anyah et al., 2006), with future projections still showing more rainfall and temperature variations (Aloysius et al., 2016), then credible climate study are still needed so as to galvanize people's understanding of climates of the Lake Victoria Basin. Furthermore, general people's perception of climate change is still evolving with more science base researches, while the effects of climate change on rural household livelihood in the region is still not well documented. A government survey documented that a severe weather experienced in the region accounted for approximately 90% of all-natural disasters (GoK, 2010), we can therefore conclude that changes in climate have significantly increased human vulnerability. It is also imperative to point out that frequent, persistent droughts and regular floods pose great risks to the larger population, whose livelihoods depend on climate base resources.

The concerted efforts in climate modeling aimed at providing accurate results seem to show a future climate that is marked with an increased temperature trend, unpredictable rainfall, and severe drought episodes in different regions (IPCC, 2001, 2007 & 2014). Furthermore, severe rainfall is likely to increase flood events while the lack of it will exacerbate drought, hence causing food shortages and climate-induced internal migration. Based on such projections therefore, there is a need to re-examine the results of current climate models used to capture future climate scenarios of LVB. Change in climate is certain to have a ripple effect at all levels in the region but more pronounced at the household level. Consequently, a decline in the source of their livelihoods are likely to experienced which therefore, requires proper mitigation and adaptation measures are required to be more focused on both the now and the future events. The high poverty levels experienced within the basin (Kangalawe et al., 2008) is likely to hamper such efforts thus subjecting more population to misery. It is essential to understand, however, that not all the current or future household mitigation and adaptation strategies can address the impact of climate change. As such, the impact of climate change is likely to have far-reaching effects on household livelihoods in various regions of the world including the Lake Victoria Basin of Kenya. Future climate projections in the basin still show an increased temperatures and increasingly variable rainfall patterns with spatial, temporal characteristics (Warner et al., 2013).

Households' vulnerability to changes in climate is likely to vary with the ability to mitigate and adapt to such events. Several factors have been documented that contribute to the vulnerability of smallholders to climate change impacts namely poverty, overreliance on natural resources, subsistence nature of their production, and limited adaptive capacity (Yaro, 2004; Pavola, 2008; Abdul-Razak and Kruse, 2017; Simotwo et al 2018). However, there exists no universal agreement on the parameters of quantifying climate risks at the household level (Palmer & Räisänen, 2002). This study, however, focused on rainfall and temperature indices and how they affect household livelihood within the basin.

The main livelihood of the population in the Lake Victoria Basin revolves around climate-related activities such as rain-fed agriculture. Substistance farming for instance, is a source of household food and economic income for most rural households in the basin. Changes in the climate regime in the LVB is likely to have a far-reaching effect on the households (Osima et al., 2018). There is the likelihood of climate variability and change, causing further inequalities among the population, with households, which never experienced long droughts and floods between seasons further sliding into poverty because of lack of or the under-utilization of available assets. Currently, there exist knowledge gaps in the climate change effect on household livelihoods in the Basin. Today, most households make extremely risky decisions with available assets to stabilize their livelihood systems necessitating the need to constantly monitor and document climate change with the goal of lessening the risks.

### 1.2.1 Research Questions

This study sought to address the following questions:

a) What is the spatio-temporal climate variations in Lake Victoria Basin of Kenya Using rainfall and temperature indices?

b) How is the current climate change affecting rural household livelihood in the Lake

Victoria Basin of Kenya?

c) Which climate change adaptation strategies are employed by rural households in the Lake Victoria Basin of Kenya?

d) What are the possible future climate change scenarios in the Lake Victoria Basin of Kenya?

## 1.3 The Objective of the Study

The general objective of this study was to analyze the spatio-temporal climate change and its effects on household livelihoods in the Lake Victoria Basin of Kenya.

### 1.3.1 The Specific Objectives of the Study

The specific objectives of this study are:

a) To assess the spatial and temporal variations in Lake Victoria Basin of Kenya using rainfall and temperature indices.

b) To analyze the effects of the current climate change on rural household livelihoods in the Lake Victoria Basin of Kenya.

c) To establish climate change adaptation strategies employed by the rural household in the Lake Victoria Basin of Kenya.

d) To determine the future climate change scenarios in the Lake Victoria Basin of Kenya.

## 1.4 Significance of the Study

Lake Victoria Basin of Kenya has various natural resources that support household livelihoods. These resources, however, are climate-driven and, therefore changes in climate increases the level of household livelihoods vulnerabilities. The mounting need to frequently update the knowledge on the spatio-temporal distinctiveness of the climate change in the region cannot be over emphasized. However, with limited understanding still existing, the present and future climate changes will continue to affect the rural household livelihoods. If a solid climate change knowledge base is not established, then many households are likely to use a try-and-error approach to fast-track fight their livelihoods which is already susceptible livelihoods, due to extreme poverty experience within the region. The 'Firth Assessment Report', IPCC (2014b), projected the likelihood for severe, pervasive and irreversible consequences in the region and beyond due to increased global warming. A proper understanding of climate variability challenges within space and time, which this study is anchored, will no doubt help to minimize climate change effects at household level. Therefore, a pragmatic understanding of both the current and future climate scenarios is vital in determining the current and future household vulnerability, exposure and response. Such determination of changes in climate and its effect on rural household livelihood is still scanty. Attempts to bridge such gaps are made a priority in this study, with the aim of uplifting the quality of life at the household level.

The need for prompt and accurate climate information by the policy makers continues to grow. Policy makers need to understand complexities emanating from changes in climate while, trying to address climate change daunting task. This study therefore, sought to improve such understanding climate change and offer a better-informed solution to rural households locally and perhaps to be implement as a pilot study at regional, national, and global levels. In order to facilitate policy formulation, study integrated diverse kinds of knowledge on climate science and explicitly engaged the households from across different agro-ecological regions for better understanding the effect of climate change. Unlike previous studies, this particular study too, underscored coupled human-environment systems rather than focusing on just households or climate systems in isolation.

This study therefore, establishes a firm base for policy decision making, supported by both climate and household information that candid to Lake Victoria Basin of Kenya. The focus rural households in different agroclimatic regions therefore, was to provide a context in which dynamics of human and climate systems play out in different ways and places a necessary element in policy formulation.

Several of climate-related challenges have been observed in the basin, they include; prolonged famine, droughts and floods which is attributed to increased rainfall intensity and land-use changes. Such challenges are likely to have serious implications for human livelihood at a household level. Extensive studies (Kates at el., 1985) established that the impact of climate change on food security, availability of water, and energy use. While, recent studies have exposed the severity and complexity of these climate-related challenges. Even though the Basin is regarded as one of the rich agricultural potential areas in Kenya, temporal rainfall variability experienced in the area (Wabwire et al.,2020; Kizza et al., 2009) is likely to hamper the productivity causing great challenges on household livelihood. This study investigated both spatial and temporal climate change, within the LVB in the past forty years, with future projections spanning to the 21st century aimed at weighing the current and future climate trends. Climate change adaptation strategies depend on some factors such as; distribution of wealth within the society, access to information and governance structures to deal with societal concerns. The study sought to generate new knowledge on the topic of climate change and impact on human livelihood. The study will thus fill the existing literature gaps concerning the topic of study prior to working on this research and opening up new other frontiers for future researchers.

## 1.5 Justification of the Study

The general perception of the people is that climate change has always occurred historically, however, the severity and the magnitude of the current changes seems to be more worrying. There are a number of indicators for these changes, for instance, temperatures rise, extreme droughts are becoming longer and increase in rainfall variability all observed in the Basin.

The changes observed in the basin could likely be caused by either the natural or anthropogenic factors (human-induced) factors. The latter however, is blamed to have increased greenhouse gases in the atmosphere that have triggered changes on a global scale thus affecting the Lake Victoria Basin of Kenya. Available literature Selwood et al., (2015) further, suggested that changes in climate may well be triggered by land-use changes, such as deforestation due to agricultural or settlement activities, results into changes in the surface albedo hence prompting changes in a climate system. If this is anything to go by then, then population increase within the Lake Victoria Basin of Kenya could have caused extensive change in land use hence accelerating the changes in climate.

## 1.6 Scope of the Study

The Lake Victoria Basin of Kenya was the geographical scope of this study. The choice of the basin was timely considering the existence of increased extreme climate events which are linked to climate change observed in the region. The Basin has a densely populated area with the majority of people being rural poor. The main social and economic activities in the basin rely on rain-fed agriculture which predisposes the rural population to high climate change vulnerability as compared to the available urban household whose livelihoods are diversified so as to be less vulnerable (Omwega et al., 2006). It is therefore relevant to study the effect of climate variability on household livelihoods.

This study focused on rainfall and temperature indices of climate change for period between 1971-2016, and the base the period of 1957-1970 to establish the changes in climate within the region. The two indices of climate change were found to be the best in determining changes in climate in the Lake Victoria Basin. To ensure adequate spatial representation, four agro-ecological zones were used in this study. Furthermore, the zone also formed a sampling frame for the households considered in this study. Only household heads were considered the main and only respondents for this study so as to achive its objective. The household head respondents must have fulfilled the following requirements; they must have from the selected agro climatic zones to ensure spatial representation, must be from a rural setting characteristic, must have lived in the region for a longer period and finally the household livelihood activities should largely be climate controlled.

## 1. 6 Operational Definitions

**Adaptive capacity**: The ability of systems, institutions, people and other organisms to adapt to possible changes, to seize opportunities or to react to the consequences of climate change. (IPCC, 2014).

**Climate adaptation**: the long terms livelihood alteration measures that help the household to come with negative effects of climate variability (IPCC, 2007).

**Climate adjustments**: the short-term adaptation measures employed by households to prevail over the negative effects of climate change (IPCC, 2014).

**Climatic variability**: The variations in the mean state and other statistics (such as standard deviations, the occurrence of extremes) of the climate on all spatial and temporal scales beyond that of individual weather events (IPCC, 2007).

**Climate Change**: The state of the climate, which can be identified (using statistical tests) by changes in the mean and / or the variability of its properties and which persists over a longer period of time, usually a decade or more. (IPCC, 2007).

**Climate model ensemble**: A group of corresponding model simulations used to provide possible climate scenario.

**Climate Projection**: a forecast of the climate system response due to emission or concentration scenarios of greenhouse gases and aerosols, or radiative forcing scenario often based on simulation by climate models (IPCC, 2007).

**Climatological norm**: a period of climate investigation which covers a period of 30 years average for a weather variable.

**Food security**: This is a situation in which all human beings have physical, social, and economic access at all times to adequate, safe, and nutritious food to meet the nutritional needs and dietary preferences for active and healthy lives. (FAO, 2009).

**Rainfall onset and cessation**: An onset is considered to be the first wet day (1 mm or more) of one or two consecutive days totaling at least 20 mm without any 7-day dry spell (totaling less than 5 mm) during the20 following days. When this condition is reversed, we consider that to be a cessation (WMO, 2012).

**Spatio-temporal**: it is an investigation of a phenomenon which focuses on the area and time dimension of events or data.

**Sustainability:** it is the resistant to external shocks and stresses and its ability to maintain the long-term productivity of natural resources without undermining the livelihoods of others. (Kollmair et al., 2002)

**Sustainable Livelihoods**: A livelihood capable of handling pressures and shocks and recovering from maintaining or improving their capabilities and assets without undermining natural resources. (DFID, 2002).

**Sustainable development**: It is a development that uses locally available natural resources to meet the needs of the current generation without compromising the development needs of the future generation by maintaining the viability of an ecosystem. (Encyclopedia of Ecology 2008).

**Rainfall Variability**: Observed short-term inconsistencies in the precipitation for a short time scale of months.

**Vulnerability**: the potential threat posed by climate variability and change on households.

# CHAPTER TWO

## 2.0 LITERATURE REVIEW AND CONCEPTUAL FRAMEWORK

### 2.1 INTRODUCTION

Literature review provided a critical examination of existing literature related to spatial and temporal climate change and, how those changes affect the rural household livelihoods. The literature review therefore, sought to establish scholarship research gaps on the degree of climate change and to also show how some of the reviewed literature would be employed to advance the argument therein. In order to do this, the literature review is thematically outlined based on the research as shown in the sections that follow below.

### 2.2 Spatial and Temporal Characteristic of Climate Variability and Change

Climate changes occurs within space and time, where each region is a manifestation of specific changes. This subject has attracted a multidisciplinary discussion and debate. To unravel such discussion, a time-related study on spatial changes for precipitation and temperature in East Africa was done for period 1951 - 2010, using GPCC and CRU datasets, (Ongoma, and Chen (2017). From late 1960s to 2010 a rise in temperature was recorded and, a further trend changes 21.76 mm occurred in 1994. By 1992, the temperature increament was at a notable degree. In 20$^{th}$ and 21$^{st}$ century, Anyah and Qui (2012) analyzed the attributes alongside variations of precipitation and temperature in the Greater Horn of Africa. The study used model outputs from a sample of CMIP version 3. It revealed that all the models used to simulate East Africa climate overestimated peaks in both the October-December; March - May seasons. The study however established that models were consistent in exhibiting the extreme climate events in the region.

El Niño-Southern Oscillation as an example of major events has adequately been addressed in available literature. Stager et al., (2007) investigated the link between the sunspot's activities and El Nino episode on Lake Victoria in Eastern Africa. This study suggested that sunspot activities led to positive rainfall anomalies a-year or there about prior to solar-maximum. The study significantly revealed Sun- Rainfall relationship was persistent and anticipated to carry on over a period of time thus recommended systematic monitoring of sunspot cycles as a long- term strategy of predicting precipitation anomalies in much of East Africa. A study by Schreck III and Simazzi (2004) examined the most prevailing method of change and variation across East Africa based on CMAP data. It was observed that El Niño–southern oscillation (ENSO) and decadal variability of climate significantly affected regional climate changes. These challenges of climate change therefore, could be said to emanate from such aspects of weather as flooding, seasonal dry spells, frost or storm as documented by IPCC (2001).

In other regions facing similar challenges, Gaughan and Waylen (2012) investigated the inter-annual regional precipitation variability before and after the late 1970s for period 1950 to 2005 along South Africa's catchment areas of Okavango, Kwando and Zambezi. The result showed that the rainfall variability corresponded with the region's frequency of occurrence of ENSO. However, negative rainfall trend increased dry years with warmer periods of ENSO observed across all three sub-catchments. Consistent with other studies on El Niño–southern oscillation (ENSO), Nicholson (1996) had earlier observed a relationship in Rainfall fluctuations in rain and ENSO phenomenon in Eastern Africa. It was certain that rainfall trends were above average during ENSO years. However, the main rains were found to have less variation and inter-annual changes were linked to variations of short-rains.

Broman et al (2020), Bayesian dynamical linear modelling of seasonal precipitation and change in sea-surface temperature in twenty-first-century, revealed similarities between changes in precipitation and changes its main dynamical features. The Kiremt season precipitation observed mainly in Ethiopia had emerged as a new regime and therefore, keen interest was needed to focus on accurate forecasts of such precipitation so as to make operational decisions on the agricultural and water resources for the communities who relied on them. In West Africa, a study on Spatio- temporal features in previous rainfall-recuperation with data collected from 167 (254) stations for the 31- year period between 1980–2010, complemented with gridded ARC2 data (period 1983–2010) indicated extremes in rainfall and non- significant rainfall trends along the Guinea Coast, except for extreme rainfall related indices (Sanogo et al.,2015). Similar study was done by Jury, M. R. (2013) in Southern Africa for period between 1900-2100 using ten observed, reanalyzed and model-simulated climate data sets. The result exhibited an upward trend in temperatures while rainfall trends was not found due to minimal in many datasets.

It is not obvious to project the impact of ENSO and its El Nino phenomena in the LVB, a study by Stager et el. (2007) however, showed that the 1997 El Nino episode triggered floods and high rainfall resulting into a surface rise of about 1.7m in Lake Victoria. The El Nino phenomena further, disrupted agriculture production and pastoral system. While the El Nino has been associated with extreme rainfall, in some regions it has triggered severe drought significantly decreasing H.E.P output that limited the availability of electricity in East Africa. Future projections of variation in prevelance, magnitude and rainfall predictiveness would impact individual livelihood with regards to water availability, reduced household income and decreased agriculture production. In the LVB region which heavily depends on rainfall for agricultural activities, it could result to widespread food shortage.

In Eastern Africa, climatic changes have contributed to fast onset and cessations of rain, besides prolonged and intensified droughts that have been observed by Eriksen et al. (2005) which overburden the household with labour. Such drastic changes and future climate projection could threaten household food productivity, increase water stress and limit household income generating activities (Luhunga, 2018). Studies have linked climatic changes to an increase in global ocean heat content since the late 1950s; with more than half the heat increase concentrated in the uppermost part of the ocean, about 300 meters, where an average temperature rise of 0.037º C/decade (Schlesinger & Mitchell, 1987). This increased temperature has led to frequent and severe drought due to low precipitation.

## 2.3 Climate Change Effects on Rural Household Livelihoods

Human livelihoods are peoples' abilities, possesions, tasks and means of making a living (Scoones, 1998). Consequently, sustainable livelihoods can be achieved with an opportunity to obtain assets and capital. Brocklesby and Fisher (2003) study reviewed extensively sustainable livelihoods approaches, by explaining what they are and, how they emerged. They study also examined organizational perspectives to establish consistency with community development thinking and practice. It revealed gaps in actualizing sustainable livelihoods. In the conclusion, sustainable livelihood approaches that embodied a technocratic development drive was seemingly being overemphasized. This current study underpins Sustainable livelihoods that is congenial with household needs, thereby protecting the natural resource base without which the livelihoods for rural households would be jeopardized.

In most rural societies, the smallholder's agriculture forms a broad base for household livelihoods. Furthermore, smallholders in rural areas of Africa, south of the Sahara depend on rainfed agricultural activities susceptible to impacts of climatic changes. Makuvaro et al (2018) sought to sensitize smallholder farmers of Lower Gweru Communal area of Central Zimbabwe on climatic changes, consistent with their perceptions of the projected climate of Zimbabwe by 2050. Data from a total of 60 farmers drawn from six villages in Mdubiwa and Nyama Wards, revealed devastating effect of climate change on smallholder farmers. Mikalitsa, S.M. (2010) assessed gender-related hindrances on the adoption agricultural technology and access to food in Kenya's Western region. The study which was based a multi-stage stratified random sampling design, revealed that land property ownership, agricultural extension services, access to credit facilities, income sources and low education level were the leading limitations facing women smallholders. The study recommended dissemination of available and new technology to small scale farmers through agricultural extensions.

Ubisi, et al. (2017) examined perception of small-scale farmers in Limpopo Southern part of Africa, on effect of climatic changes on farming and individual livelihood. 150 questinnaires were distributed to these farmers supplemented with eight focus group discussions. The study findings revealed that subsistence farming was susceptible to climatic changes owing to less resources. The study recommended extension services to assist small farmers cope with changing climates.

Alma, A. K. (2010), investigated the Nature Based Tourism supply system in the face of climatic changes at lower Mustang; using a multi-methods qualitative approach it established that the Nature Based Tourism supply system was exposed to changes in climate. The study further showed that owing to historic environmental experiences rather than empirical information, individuals had extensive levels of awareness and perception on variability of climate seen to influence nature-based tourism.

While there exists substantive literature on climate change (Field, 2014; Fankhauser & Richard, 1997) much of this information seems to focus on science-oriented climate variation and change on both regional and global scale. Consequently, very little research attention has been given to understanding rural households' perception on climate change. A departure from this norm, Sullo, et al., (2020) investigated the rural part of Ghana on local understanding of signals in detemining climate change. The descriptive study was based on data gathered for two hundred-and-eleven individuals from the area. It indicated that indigenous knowledge was vital in determining changes in climate and its effect. The study recommended scientific and technological inclusion in indigenous knowledge for effective policy and strategy framework. Alam (2017) also studied perception of rural individuals of Bangladesh regarding climate change and adoption of strategies. The study which adopted a survey design was based on three-hundred-and-eighty individuals susceptible to soil-erosion. Findings were closely related to the observed data on climatic phenomenas. It recommended financial and strategic informational access to support susceptible individuals thus increase adoptability.

In Africa, juxtapositions on climate change effects on agricultural income and especially the Sahel region shows that changes in climate have negative effect across the whole of Africa (Dube et al 2016). The study further revealed how agricultural yields have dwindled and bio-diversity reduced over time. The need for diversification in livelihood strategies were deemed paramount, anchored on proper policy-framework for incorporating the less fortunate regions solely dependant on agricultural produce and natural resources for survival. The changing nature of climate risks due to climate variability is not any new, Conway and Schipper (2011) revealed that future scenarios of climatic changes would heavily affect agricultural production as well as national GDP in many developing countries. Their study suggested that rainfall behaviour in Ethiopia showed no marked emergent changes and future weather predictions showed continuity in warming and varied rain design. These studies highlight the fact that while effort has been done to understand climate change effects, the Lake Victoria Basin of Kenya has received unsignificant attention. Furthermore, most available studies tended to be on regional and national scale, the household level understanding has been elusive in most literature. Therefore, the available literature on climate change effects at a household level remains scanty. Adding weight on this fact, Ford et al. (2016) acknowledged the fact that the interface between science and effects of climatic changes on agricultural household also remain unsolved.

Changes in climate remain as key universal environmental issues occasioned by daunting issues surrounding development thus prompting global conferences as well as conventions. During the COP 21, held in Paris between 30th November 2015 to 13th December 2015, almost all nations came together for a common goal of combating climate change and devising an efficient way of adapting to its effects. The effort of the conference was aimed at enhancing support to the developing countries. There was a consensus that individuals had been disrupted by world changes in climate posing a risk to working lives. Further, impacts are felt by individuals whose employment depends on agriculture (Gukurume, 2013). According to Downing (1992), climate variability and change still presents an unwarranted prospect to rural individuals reliant on rainfall for farming to earn a living. For most regions, changes in temperature and precipitation could evidently affect earnings from agricultural production, raise prices to consumers of agricultural products (Falco et al., 2018). Similarly, the same could bring about a scarcity of food in most households. FAO (2010) report confirmed that in most countries, agriculture facilitate household food security. Therefore, when agriculture gets affected, it increases food insecurities. Food obtainability and excellence of accessible food, determine the nutritional value on the human population. Therefore, if nutritional adequacy is not safeguarded the healthy functioning of the body and mind is destabilized. Additionally, increased pests affect crop production such as reduced crop production. Studies such as Downing (1992) showed that climate change is characterized by reduced crop production and depletion of some species of crops. Since climate change get characterized by high temperatures and sometimes prolonged rainfall, most food crops do not thrive very well in such an environment. The climate extremities caused by heat waves and prolonged rainfall destroy crops making some to be extinct.

Gander based effect of climate change has been established in region (ibid). According to Mainlay and Tan (2012), climate variability leaves women more susceptible and worse off than men. Famine and dropping of the water table can get linked to the effect of climate variability. Lama (2010), argued that individuals were concerned about the drying up of water sources in the prevailing spring. This led to the problem of fetching water from the new source by women. Additionally, Karki et al. (2017) argues that that unobtainability of water supply affects menstrual cleanliness among adolescent girls, particularly in poor societies. Similarly, the water shortage hits hard on woman's routine, as they have to cope with the domestic and kitchen, compromising their useful time on schooling and well-being.

Climate change also leads to human migration. Davis (2018) indicated that when variability alongside climatic changes become extreme, people will migrate to areas where the climate is favourable which will in turn result in over-crowding in these areas. For instance, congestion in an area results to various unwanted effects on human livelihoods since it leads to the unemployment and poor health services. Extreme climate also increases morbidity and mortality because most people will not be in a position to access basic needs due to lack of income as well as employment (Kjellstrom et al. 2020; Riley et al. 2018).

Denton, F. (2002) study on gender matters of vulnerability to changes in climate, impacts, and adaptability, established that females comprised seventy per cent of people in the third world countries living on under $1 daily. Despite the prevailing issues, decision makers have not been influenced towards gender mainstreaming, which would have placed women at the center of sustainable policy development and implementation. The study proposed for climate change policy re-aligning with the interests of all stakeholders in ensuring a sustainable development and environment issues.

The vulnerability of the coastal communities cannot be overemphasized; from altered ocean currents to salinity intrusion, from heavy and erratic rainfall to flash floods, the situation has forced some people to search for other means of livelihood (Cinner et al. 2012), for some households whose livelihoods is agro-ecologically dictated they have had to integrate other activities to supplement agriculture since it's no longer dependable (Dube et al. 2016). Extreme climate events have forced people to migrate from their homes in search of a means of survival. Such changes in climate are not only a major global environmental challenge but also a problem of great concern in third world countries. Most households in Africa are likely to find themselves victims of such problems which have a direct impact on the livelihood strategies thus triggering climatized migration. In the Northern Hemisphere, climate change is said to have increased global average surface temperature, resulted in sea levels rise and a decrease in snow cover, forcing people to move (Brown & Mote 2009). Davis (2018) study revealed that variation in climatic conditions impacted the habitat globally, while still significant and unprecedented occurrence are projected in the coming decades. Other studies on agriculture and migration established, climatic changes would negatively affect the world's economic state further linking it to sustenance and migration (Falco et al., 2018).

### 2.3.1 Climate Change Effect on Biodiversity

Climate is one major factor that affects the spread of flora and fauna (Pelc et al.,2017). In addition, it influences species seasonal activities such as flowering for plant and mating for the animal. Urban et al., (2016) looked at improvement forecast for biodiversity under climate change. The study emphases the need for relevant data collection for enhanced comprehension, anticipation and minimization of related issues. Climatic changes pose inevitable challenges on the habitat and general ecosystem that supports life. On the other hand Parmesan (2005) argued, those changes in climate could stimulate the species' biological behaviour. Species Distribution Model showed that some species are likely to expand their habitat in response to changes in climate (Guisan & Thuiller, 2005). Parmesan & Yohe (2003) further established that species that could easily migrate, significantly changed their distributional range due to changes in climate.

According to Root & Hughes (2005), plant species change the phenology in response to climate variability in the mountainous ecosystem. Consequently, most plants, insects, and animals' reproductive behaviour modify as a way of responding to warming trends.

In addition, functions of the ecosystems could be reduced by climate change; for instance, wetland regions have significantly declined due to persistent droughts. Consequently, people who often depend on aquatic resources are affected as well. Chidumayo et al. (2011) established that in Africa, climate change significantly has affected forest resources thus depriving people's livelihoods that are forest-dependent.

Ngarakana-Gwasira et al.(2016) assessed role of climate change on transmission of malaria across the African region. It revealed that rainfall and temperature indices of climate change played a vital role in malaria transmission The study alluded to increased constraints of malaria owing to climatic changes. Consistent with the previous studies, Onyango et al.,(2018) on malaria distribution case of East Africa concluded that El Nino, rainfall influenced malaria vector.

Le et al., (2019), further investigated how variations in climate influenced malaria across the rural region in Kilifi county. The study established that temperature affect cycle of malaria parasite while moisture affected cycle of mosquitos, consistent with the other studies. Considering available information, it can be said that climate change is characterized by increased multiplication of pathogens and pests that cause diseases such as malaria. In this regard, increase in temperature creates a good environment for pathogens to multiply leading to outbreak of diseases (Le et al. 2019; Lama, 2010).

### 2.3.2 Climate Change Effect on Agriculture and Food Security

Lake Victoria Basin climate is under control of a very complex system that comprises a low-pressure belt around the Lake Victoria and land interaction. The system produces a variety of agro-climatic zones that exert significant control on smallholder farmers. Such a situation subjects the household to high climate risks and vulnerability already extensively been discussed (IPCC, 2001b; IPCC, 2007). These reports have been categorical about high vulnerability in Africa owed to the people's low adaptive capacity. The general consensus is that climatic issues remain a growing challenge to agriculture and further, disrupting food stability through the alleviation of poverty. Antwi-Agyei et al.,(2013) established a number of elements that subject household to high clamate risks; in Ghana, for instance, they suggested that these factors include overdependence of household on rainfed agriculture, lack of diversification on household income and limited access to reliable climate information. Furthermore, Ambeje et al., (2011) reported that climate extremes observed in some parts LVB Kenya have contributed to a shortage in the food supply, limited access to income and needed social services. El Nino related events are reported (Indeje et al., 2000) to cause changes in weather patterns in some parts of equatorial-subtropics of East Africa. The erratic weather patterns experienced within Africa between 1980-2000 tripled the food crisis per year (FAO, 2004), while droughts diminished water supplies (Gan et al., 2016) and a decline in crop production which caused rampant famine faced in Africa. For instance, in Kenya, a good proportion of her vulnerable population depend on climate base resources which are affected by frequent drought event (Tumushabe, 2018), and flooding which are some aspects of climatic changes.

Akudugu et al. (2012) reported that Africa is experiencing a serious food shortage that is triggered by an increase in persistent droughts and, in 2010, out of twenty-two countries characterized by the Food and Agricultural Organization to be in serious food crisis, seventeen were Africa (FAO, 2010). The report further, estimated that between the years 2010-2011, people affected by food insecurity had more than doubled in Africa due to erratic weather conditions. The IPCC (2007b) report further revealed that 1/3 of people in Africa are living in areas inclined to drought. In Tanzania, it was observed that climate change had a serious impact on food production due to a 3.3 % decade decrease in rainfall (Mbilinyi et al., 2013). With the projected increase in drought every five years (Herrero et al., 2010), this is likely to cause a further decline in the numbers of livestock in ASALs and reduced cropping in vulnerable areas. The food Prices could drastically increase due to food inaccessibility. This translates into increases in malnutrition, especially of young children (Thorne-Lyman et al., 2010; Cornia et al., 2016). Largely, empirical evidence on climate change has tended to focus on ASALs the present study focusses on regions considered humid climatic zones.

### 2.3.3 Climate Change Effect on Water Resources

Water resource is extremely reliant on climate therefore, climatic changes would significantly interfere with its spatial along with temporal dispension (Konapala et al., 2020). On account of such climate related issues and other prevailing circumstances such as demand for water, some countries in Africa experience substantial water stress. A study by Hiscock & Tanaka (2006) showed that an increased global temperature had resulted in changes in precipitation patterns and soil moisture which in turn has contributed to variation in runoff and groundwater recharge.

According to Hiscock (2005), an increase in the rate of evapotranspiration could result into floods and drought in some areas which can cause water stress. As the population rapidly grows, the demand for groundwater is likely to increase even further. A general consensus shows changes in water resources is affected by extreme climate events rather than normal climate variabilities (IPCC, 1990). Ngigi (2009) on the other hand established a correlation between increased evaporation and the concentration of solutes, which leads to increased water salinity, while Dragoni & Sukhija (2008) established a relationship between increased evaporation and deficiency in soil moisture content. Places with depleted soil moisture are expected to have reduced vegetation, which certainly affects the hydrologic cycle. In wetlands regions, precipitation helps with water recharge. Wetland in themselves offers critical grazing areas in ASALs.  Extreme climate events would degrade the wetlands thus decrease functions.

## 2.4 Climate Change Adaptation Strategies

Science around climatic variations as a subject has attracted multi-disciplinary approach. Eriksen et al., (2005) study established guidelines on coping with climate issues thus illustrated a need for sustained adaptability for socio-economic sustainability. Nelson et al. (2007) defines these strategic actions as the ways people adjust to and trade-off the cost and benefits of climate variability. Smit et al., (1999) further, distinguished two kinds of adaptation strategies; an autonomous and planned adaptation. Adoptability calls for addressing appropriate coping strategies. Such strategies will enable a household take appropriate actions to address extreme climate events for both short- or long-term measures.

Studies in Ghana on adaptability of small scale farmers indicated low adaptation with education and gender variances (Abdul-Razak & Kruse, 2017). Female farmers had low access to resources and information. Gukurume, S. (2013) who conducted a similar study in Zimbabwe identified the poorer community farmers suffered climate stress greatly as they are heavily dependant on agriculture for a living. It was also established that sush issues as low productivity, livestock-mortality and crop failures contributed to low produce.

Elum et al. (2017) sought to understand opinions of smallholders on strategies for dealing with climatic variations in Southern Africa. The data generated established that farmers practiced several activities like growing plant species that are drought resistant to cope. The study recommended strengthening of farm-insurance using the media and other surpportive programs, a concept shared by Masud et al., (2017).

Attempts towards understanding issues associated with climate variations on human society has been documented in SCOPE  27 report. The previous study (Adger, 2003), investigated climatic variability as social issue requiring social resolution thus the use of Social Impact

Assessment (SIA) as a way to evaluate suitable adaptation strategies for a society unlike other approaches. The approach further, outlines the impacts and vulnerabilities to climate change including the variability which triggers some response. Effective adaptation also requires policy responses where actions are planned and sanctioned to ensure the wellbeing of society. The strategies may also include the possibility of taking advantage of opportunities offered by climate change to better household livelihoods. The National Climate Change Action plan 2018-2022 outlines some strategic action plans that meant to reduce climate risk; these strategies included intensifying the household's numbers though operationalizating the process has been rather slow (GoK, 2018).

SIA approach, however, is prone to being biased and poses a challenge of determining the threshold on household basis. For climatological study, a threshold for determining climate variability is critical in determining its impact on effective adaptation strategies. Holistic evaluation of the challenges remains a crucial element for policymakers. This study seeks to establish effective climate change adaptation measures in Kenya's LVB. Besides, this study further investigates the households' perception of variability in climate. Communities of Northern Nigeria have employed local understanding to successfully cope with these variability (Sullo et al., 2020). The scientific method, however, has been widely used in determining various climate variability scenarios for strategizing on adaptability. This efficient approach can help the rural community to cope with the challenges without sliding further into poverty (Vanclay, 2015). A study on the Link between local comprehension and scientific knowledge to cope with climate change established that the unique and specific indigenous knowledge systems infused in western science knowledge, could be one of the best ways to the more effective and sustainable implementation of climate change adaptation strategies among target indigenous communities (Makondo & Thomas, 2018).

Cooper et al., (2006) examined the capability of coping with climatic variability by Small Scale Agriculture in rainfall reliant parts of Africa. The study established that coping was a major constraint. The study proposed an enhancement of opportunities that come with the current climate variability for better adaptation as shared by Ziervogel and Zermoglio (2009).

## 2.5 Possible Future Climate Scenarios

While climate change has become the main topic that attracts global attention, its familiarization from an enduring viewpoint is still puzzling. This is informed by the fact that spatial variations of climatic changes and variability manifest through diverse degrees of temperature and precipitation. Supporting a well-versed verdict and making strong forecasting under future variabilities is likely to simplify investigation on all likely changes to local climatology and puts a figure on the likely climate dangers to human society and natural systems (Platts et al., 2015).

The IPCC guideline offers projections on climatic predictions (cited by Mendlik & Gobiet, 2016), however, Solomon et al., (2007) indicated only 66% probability of future changes based on the fact that projections were pegged on climate emissions. Clark et al., (2016) investigated on climate and sea-level projections for the 21$^{st}$ C. The study revealed that carbon-dioxide emitted by individual activities could trigger changes in climate system. The study recommended proper quantification of climate emissions and a long-term perspective policy decision that will constantly check the emission level. However, such quantification and the certainty of emissions remain a challenge (Sillmann et al., 2013). Current studies on climate projection are faced with a challenge of credible data for plausible results. It is therefore certain that climate projection remains a pressing need considering the need for possible clues on the future climate scenarios.

Onyutha et al., (2019) for instance, investigated the observed and performance of rain across the LVB considered part of Africa's wet zone. The results revealed that Global and Regional Climate Models showed dismal results in recording temporal and intensity of rainy events.

Souverijns et al (2016) analyzed Eastern Africa's upcoming change in rainfall by classifying distribution designs for fifteen historic as well as upcoming individuals of CRCDE. The study established a decline compared to previous years with the decline projected to be more under a high emission scenario. Consistent with other climate simulation in the region, Luhunga et al., (2018) carried out predictions of climate variability in Tanzania based on RCM obtained from CORDEX, for period between 2011 and 2100 predictions in everyday rain, lowest and highest temperature RCP 8.5 - RCP 4.5 comparing to a base of 1971 to 2000 simulations. Projections indicated that LVB's west and North East uplands would have a surge in temperature between 4.5 - 4.8°C in RCP 8.5 emission. Futher, period June-September known to be cold would be very warm compared to October - April known to be warm. In June – September, there would be a surge in temperatures 1.7 - 2.4°C and 2 - 4°C halfway into 2041 to 2070 and final months of 2070 to 2100 eras. This study offers a clear indication of increasing trend temperatures across Lake Victoria and, further projection showing a further increment around one-degree celcius under A2a emissions scenario and between 2 - 3°C under the B2a emissions scenario have been reported (Ambeje et al., 2011).

IPCC (2001) report was categorical that in the $20^{th}$ century, temperatures are bound to increase by 0.7°C in Africa affecting the rainfall in the region, a further warming of between the ranges of 0.2°C (low carbon emission scenario) to more than 0.5°C (under high carbon emission scenario) was also projected. High variation in the precipitation is also reported with more rains being observed between December-February and, the reduction between June-August. As a result of escalated intervals of climatic occurances touching LVB, most households are at risk since these climatic events would result in potentialiality of undoing a decade of development efforts.

Gebrechorkos et al. (2019) used the Statistical Down-Scaling Model (SDSM) for calibration and validation of every-day-precipitation, maximum and minimum temperature in two-hundred-and-fourteen zones with projectors obtained through re-analysis of data from NCEP to predict period 2006 and 2100. The model depicted high rainfall in October to December known for shorter rains for period 2011 to 2100. It further revealed increased precipitation in Kenya and Ethiopia between March and May with decline for Tanzania during the years 2020s and 2050s as well as 2080s.

Available literature (Anyah and Qui, 2012; IPCC, 2018) suggested the use of a combination of multi-models' approach as a more acceptable technique used in carrying out climate projection. The combination of multi-models has two main domains in climate projection. The first domain is the equal weighting of models and the second domain is the optimum weighting, where models' weights are determined according to their performance. The aim of using a combination of multi-models is to estimate model uncertainties and to make a meaningful and more reliable climate projection. Whereas researches tend to use either of the above approaches, recent climate projection researches have embraced the ensemble approach which has been established to provide a more meaningful climate projection (Murphy et al., 2004). These approaches have shown more reliable and accurate information on temperature and rainfall. There are two types of climate model ensemble: The Perturbed Parameter Ensemble and Multi-Model Ensemble. Both, however, are capable to simulate extreme, inter-annual variability with time..

Loehle & LeBlanc (1996) acknowledged that the current climate simulations of future climate change need to link the atmospheric concentration of $Co_2$ to future change in climate. Based on $CO^2$ emissions two scenarios are established, one which focuses on normal emission concentration (also referred as the representative concentration pathways 4.5) and another examines changes under high emission (also representative concentration pathways 8.5). Estimation of $CO_2$ concentration, however, is almost impossible, if such estimates do not factor in potential bias and corrected, or additional uncertainties reflected (Meehl et al., 2007). Skewed therefore, the best estimate for climate projection is only valid if keen interest is on the physical and carbon cycle processes and their feedback (Appendix IV).

The growth scenario for the next 50 years by IPCC (2001) records that $CO_2$ emissions have increased by nearly 1% yearly in the past 20 years and until 2050, it assumes a zero-growth rate for $CO_2$ emissions which is constant emissions. The scenario similarly centers on radiative forcing from greenhouse gases which are non-$CO_2$. Reasonable expectations for technological advancement and human influences got projected to attain radiative forcing. This scenario result to a projected temperature rise of 0.75°C by 2050, nearly half of that ensuing from more predictable expectations. One justification for focusing on 2050 instead of 2100 is that it is additionally hard to foreknow the technological capabilities that will permit a decrease of greenhouse gas releases by 2100.

Climate projection scenarios serve as a believable illustration of future climate circumstances and other climatological occurrences. They can get created using a range of methods comprising: incremental methods where specific climatic or linked components get raised by reasonable amounts; spatial and sequential analogues in which chronicled climate establishments look like the future climate get utilized as sample future conditions; other methods for instance extrapolation and proficient conclusion; and methods that utilize a range of earth and physical climate system models comprising regional climate models. There is a distinguished rise in attention in use of climate scenarios at regional-scale for better comprehension of climatic-change ramification and adaptation valuation.

Modeling climate scenarios, however, is marked with uncertainties considering that climate system is quite complex and no single model is capable of accurately projecting future climate scenarios. Furthermore, climate models could easily overestimate or underestimate thus providing erroneous future climate projection. To unlock this challenge progress has been made to use the climate model ensemble, which is climate simulations each representing a different possible understanding of the climate. The climate projection changes are largely determined by the use of temperature and rainfall indices (Sillmann et al., 2013). The computation of these indices is done within the IPCC guidelines and UNFCC recommendation of using different emission scenarios and, multi-model ensembles. Meaningful and accurate projections require daily data available in models with high spatial resolution.

## 3.6 Sustainable Livelihood Approach

The sustainable livelihood approach (hereafter to be referred as SLA) arose during the early 1990s (Hope, S & Kempe R, 2009), as a response to changes in thinking about development as top-down processes, to one that centered more on the participation of local communities (Solesbury, 2003). The approach comprises individuals, societal, inherent, finance and material aspects (Reed et al 2013) which are necessary means of human sustainable livelihood. Other capitals have been documented such as information (Odero, 2008), and cultural and institutional assets (Cochrane, 2006). The concept of sustainable livelihood has been given special attention by DFID, (2000); it is an emphasis underpinned on its ability to manage stresses and shocks unleashed by events such as the current and future changes in climate (Figure 2.1) as well as providing for future generations and protecting the environmental resources on which it depends (Chambers and Conway, 1992)

The approach has been noted to have several strengths that are beneficial to current study. According to Kollmair & Gamper (2002), the SLA is people-centered and therefore emphasizes on people as opposed to the resources they use in earning their livelihood. Therefore, the focus on people is paramount in determining both the households' livelihood strategies and climate change indicators that affect them. The approach strongly lays a strong emphasis on the role of the poor and vulnerable people such as rural households in the society with the aim of improving their livelihood (Farringtone et al., 1999). The approach is such dynamic in nature, which makes it capable to determine climate change effect and the livelihood outcomes that shape the household's life has extensively been reviewed (Reed et al. 2013). Some setbacks have been identified with this approach (Brocklesby et al. 3003), the approach does not emphasize the need to identify each individual's household needs and problems. The approach also oversimplifies the household livelihoods realities (Smyth & Vanclay, 2017). In improving the livelihood of the specific group, for instance households, further, occurrence of negative effects on the livelihoods of another household are possible. The approach thus then create a negative dilemma in the decision-taking procedures. It therefore, does'nt factor in mediating processes such policies and market dynamics that are likely to have an effect on the household livelihoods.

The centrality of this approach however, is not only in identifying the strengths of each household but also prioritize actions for each vulnerable household. The SLA, therefore, enabled this study to make connections between people and their enabling environment that influenced the household livelihood outcomes this approach has been applied to other studies in measuring livelihood resilience (Quandt, 2018), poverty reduction *(*Sati & Vangchhia, 2016), and understanding poverty and vulnerability communities (Gee Nee & Mansur, 2015).

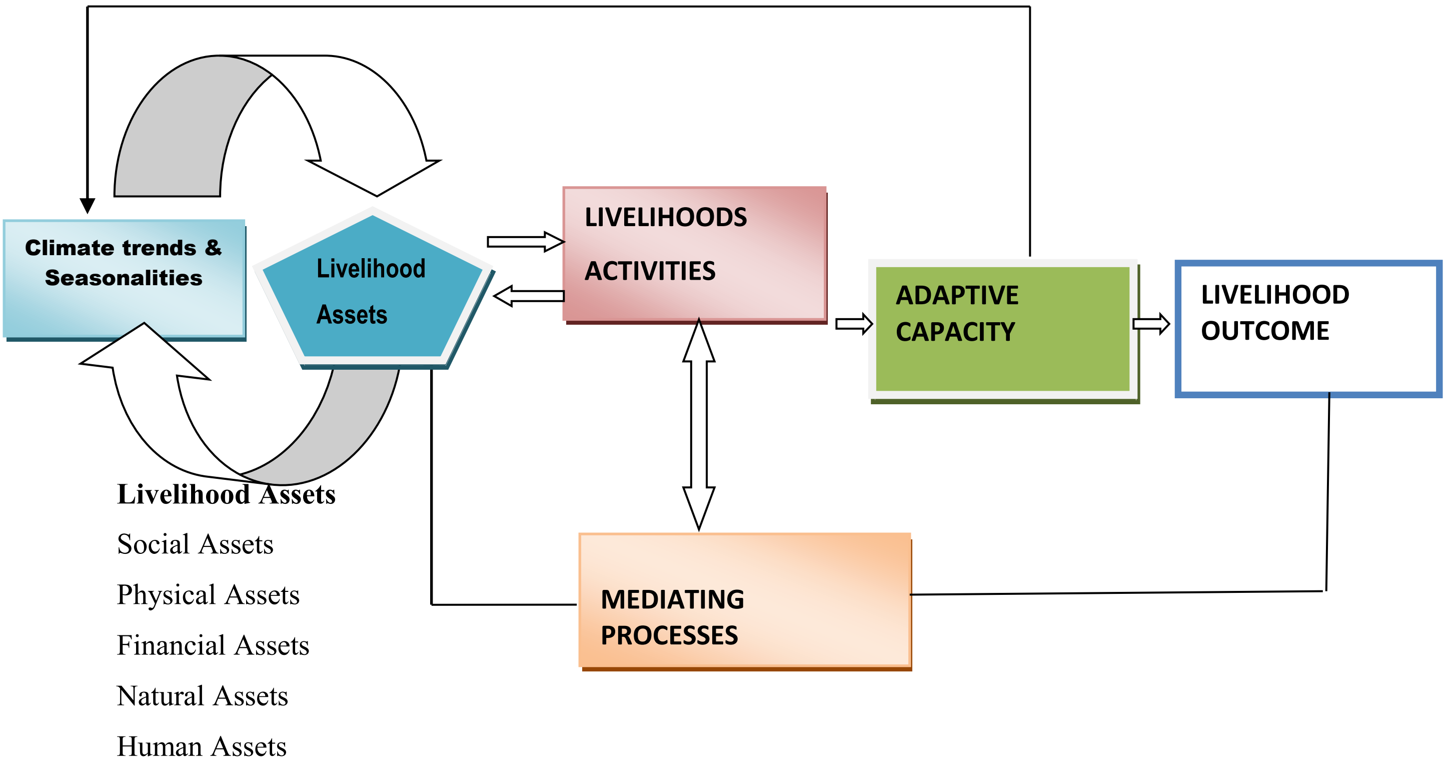


Figure 2.1. Modified Sustainable Livelihood Framework Source: (DFID 2000)

## 2.7 Conceptual Framework

The conceptual framework demonstrates the relationship between climate change and rural household livelihood around Lake Victoria Basin. The climate change was conceptualized as independent variable.  The climate change was conceptualized to include; climate variations, temperature variations (Temp $_{min\ and}$ Temp $_{max)}$ rainfall variations, change in rainfall onsets and cessations, the rainy days, extreme climate events (Frequency and severity), all of which were considered to be climate stressors that are bound to result into climate change vulnerability. The rural household livelihood was conceptualized as a dependent variable which is affected by climate stressors, non-climate stressors such as changes associated with land-use and demographics of the region under study. The stressors result into vulnerability on rural livelihood assets which include natural, physical, human, social and financial capital thus triggering the need for rural household's climate change adaption strategies. The institutional support, social relations, and policies are conceptualized as the intervening variable which play a role in controlling non climatic stressors and alleviating society's livelihood through establishment of adaptation strategies.

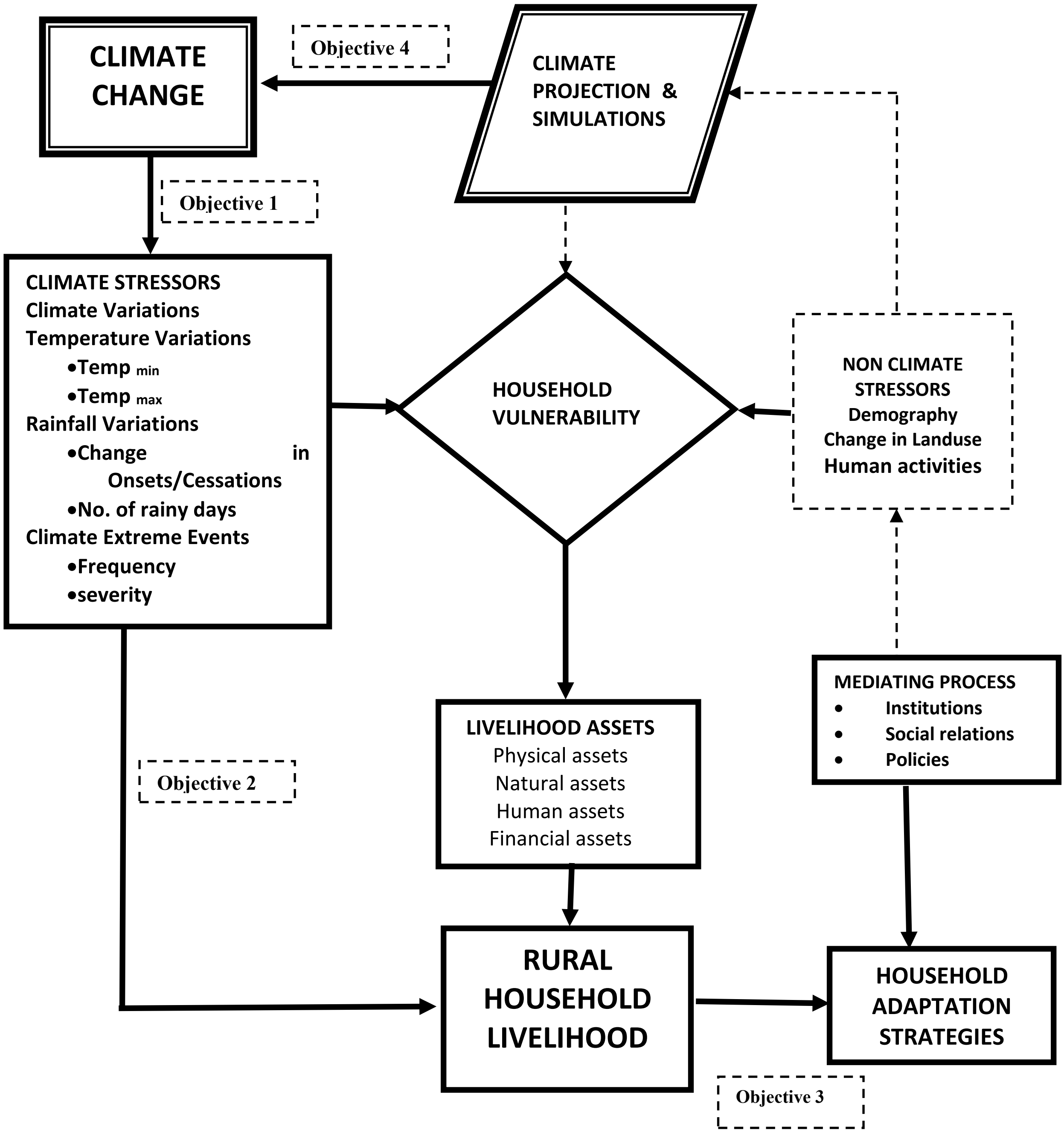


Figure 2.3: Conceptual framework Source: Modified from Smit et al. (1999)

## 2.8. Research Hypotheses

The study was guided by the following hypotheses with significance tested at α 0.05

a) The rainfall and temperature indices over Lake Victoria Basin of Kenya have not significantly varied.

b) The rural household livelihoods in the Lake Victoria Basin of Kenya have not be significantly affected by changes in climate.

c) The rural households over the Lake Victoria Basin of Kenya have not employed significant adaptation strategies that address their livelihoods.

d) The future climate scenarios over the Lake Victoria Basin of Kenya do not vary from the present climate scenario.

# CHAPTER THREE

# 3.0 THE STUDY AREA

## 3.1 INTRODUCTION

The in-depth understanding of the study is fundamental in contextualizing the spatial and temporal climate change and, it's effect on rural livelihoods which highly depend on climate-controlled resources. The discussion on study area formalizes the link between existing literature and the study findings. The chapter on study area is itemized as follows; location and size, relief, soils, climate, drainage, vegetation characteristics, social and economic characteristics.

## 3.2 Location and Size

The Lake Victoria Basin of Kenya is situated between latitudes one degree and fifteen minutes North and one degree and thirty minutes South and longitudes thirty four degrees East and thirt five degrees and thirty minutes East. This location makes the area to experience a modified equatorial region climate. The basin is an extensive geographical land extending from Mau maintain ranges to the Tanzania and Uganda borders (Figure 3.1). It covers the total area of about 38, 913 km$^2$ which is about 21.5% of the overall basin, with a coastline of approximately 550 km (UNEP, 2002). The Lake Victoria and its surrounding geomorphological characteristics cause the meso-scale circulation, consequently the weather patterns observed within the region.

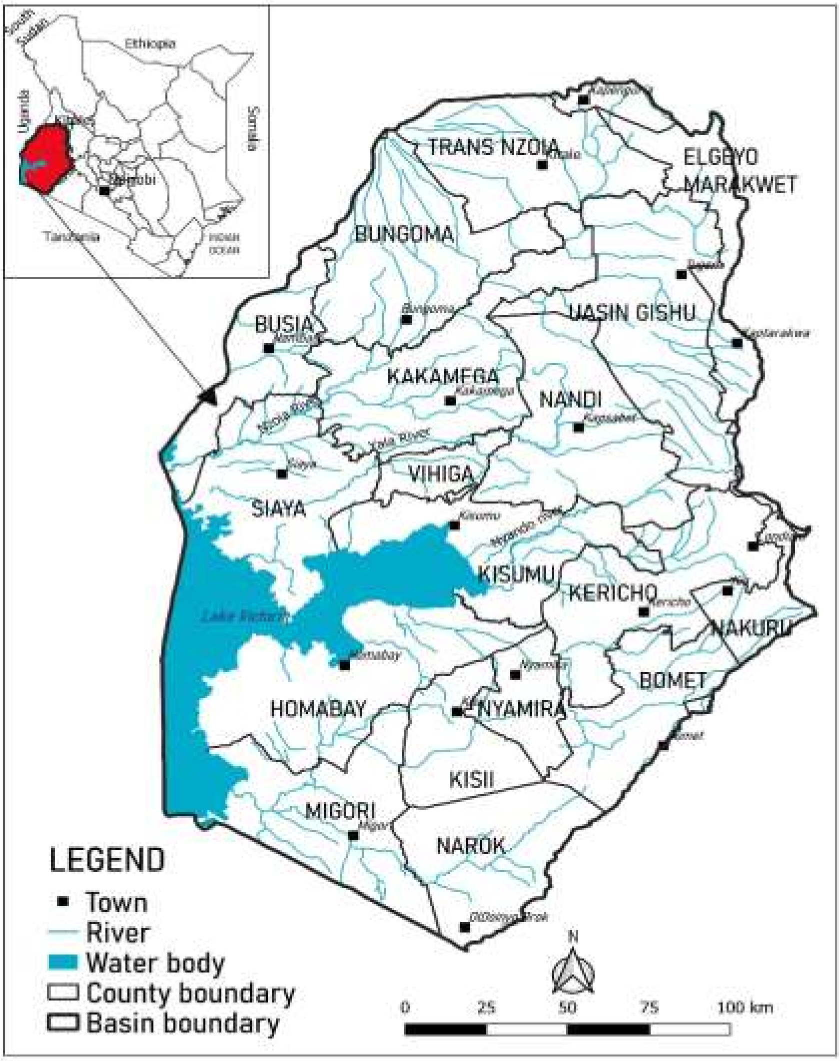


Figure 3.1: The Lake Victoria Basin of Kenya Source: Survey of Kenya, 2017

## 3.3 Relief

The Lake Victoria Basin of Kenya has a wide range of landscape pattern that comprise of plains adjacent to the lake experiencing annual floods (Kendall, 1969). The plains typically slope toward the lake and are surrounded by several hills, Escarpments close to the valley and Mt. Elgon. The altitude ranges between 1800 to 3000 meters ASL which typically affect the rainfall and the temperature of the basin. The general location of the Lake Victoria Basin of Kenya exposes the residents to yearly flood risks so inflicting major destruction on their livelihoods (Bakibinga-Ibembe et al.,2011).

## 3.4 Soils

The soils are formed from Kavirondian and the Nyanza rock systems (Kendall, 1969). These parent rocks have also influenced the soil's chemical composition as well as the colour. Other factors that influenced the distribution of soil type include the climate, vegetation, and living organisms. The soil types found in the Lake Victoria Basin of Kenya include ferrusols, nitosols, and histosols. In the recent past, human activities have also contributed to soil formation. Soils in the basin are very vital in distinguishing the farming activities in the area.

## 3.5 Climate

The Lake Victoria Basin of Kenya has a variety of climates, which range from a modified equatorial situated around the lake surroundings, to semi-arid located within the lake literal (Anyah & Qiu, 2012). The modified equatorial climate is relatively hot and humid, with significant rainfall occurring throughout the year, while the semi-arid type of climate is characterized by sporadic droughts. The bimodally distributed precipitation has been observed in the area and, it is attributed to ITCZ which crosses the equator doubly a year (Kendall, 1969). The climate variability ascertained in the Lake Victoria Basin of Kenya is a culmination of both the large –scale and meso-scale circulation. Rainfall is a vital weather component in the Lake Victoria Basin of Kenya since it is linked to most households' activities in the region (Ogallo, 1988). The wind patterns observed within the area are Congo airstream, Westerlies, and monsoon all of which have an impact on the precipitation. According to Nicholson1 (1996), the monsoon air mass which is thermally stable, is said to be the main cause of arid condition round the lake literal, whereas Congo air mass are responsible for precipitation within the lake section since they are unstable and considerably increase convection activities. The area receives an average of 50mm of rainfall monthly.

The rainfall patterns follow the ITCZ movement, consequently, the bimodal rainfall is experienced from March to May being the wettest months, while November to December experiences short rains (Ongoma et al. 2019). Annual rainfall varies between 700-2000mm (Figure 3.2). Rains are poorly distributed in the areas bordering the lake whereas highland areas receive high rainfall. In most areas, maximum and minimum temperature ranges between 28.6º C and 28.7º C, and 14.7º C to 18.2º C respectively. According to East Africa Community (EAC, 2007) report, the comparison of temperature for the period 1950-2000 to 2001-2005 showed that the maximum temperature had increased by an average of 1º C in the Lake Victoria Basin of Kenya.

LVB has over the years experienced extreme weather events as drought (Awange et al., 2007); with future projections showing drier events (Nguvava et al., 2019) such events have the potential of affecting most households in the region. Other effects of extreme weather conditions include loss of housing, destruction of infrastructure, crops, and health. A study by Arab et al. (2014) on climate and malaria episodes linked the main cause of the expansion of vector-borne diseases, especially Malaria cases being reported in highland areas where they were originally not common.

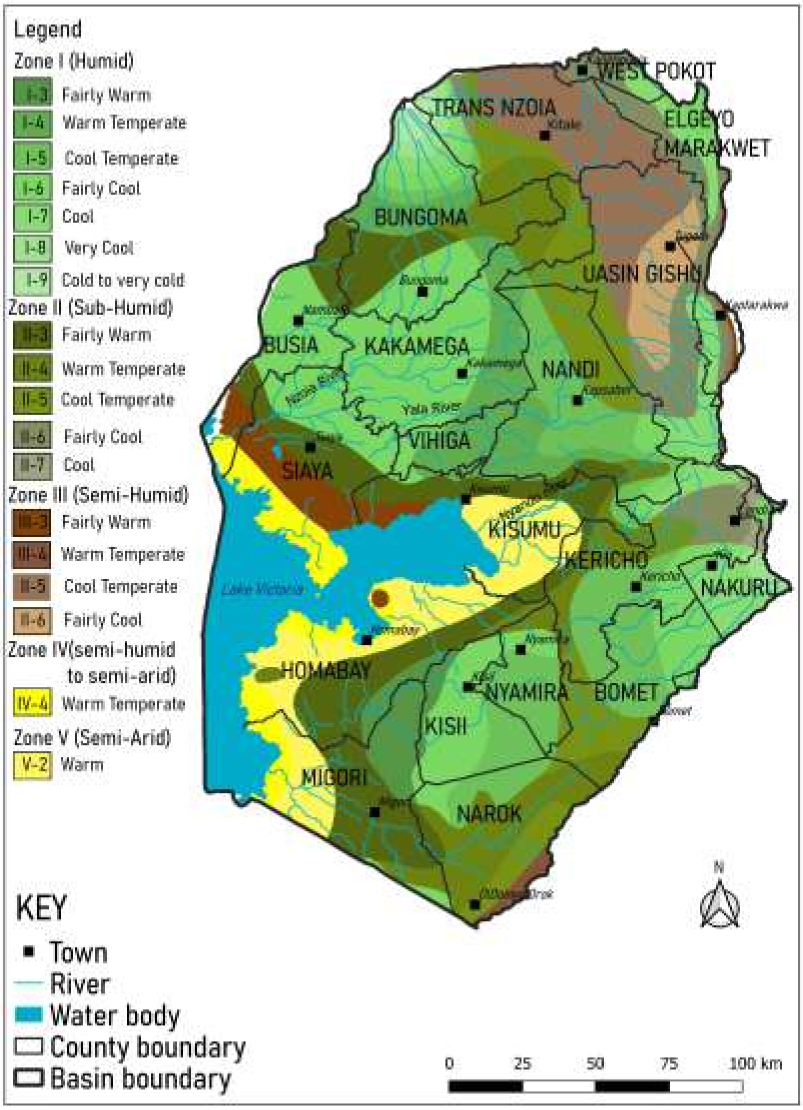


Figure 3.2: Agro-climatic zone of the Lake Victoria Basin of Kenya Source: Kenya Met. Department 2017

## 3.6 Drainage

The Lake Victoria Basin of Kenya has an elaborative drainage pattern which consists of both seasonal and permanent rivers. (Figure 3.1). The rivers have two watersheds; the Rift Valley and the western highlands. According to Lamb, as cited in Nyandega (1986), the rainfall characteristics in the basin significantly affect the river flows. The presence of the Lake Victoria and associated rivers influence greatly human livelihoods, especially with regard to water access and availability for both domestic and urban use.

Drainage significantly affects the livelihoods of most households within the basin. The rivers are the main source of domestic water supply and, other economic activities such as agriculture and fishing. The subsquent flooding at the lake literal significantly human livelihoods.

## 3.7 The Vegetation Characteristic

The vegetation cover in the study area has greatly been altered by human activities. However, the areas around western Kenya have modified equatorial forest in Kakamega, while in South Nyanza it has derived savannah. The biomass from the vegetation is the main energy source in rural households and thus is considered as a major component of the human livelihood system. Intensive land use has reduced vegetation cover in the basin consequently contributing to soil erosion which lower agricultural productivity. Riverine vegetation common to most rivers in the basin has also declined to cause an increase in river siltation (Figure 3.4).

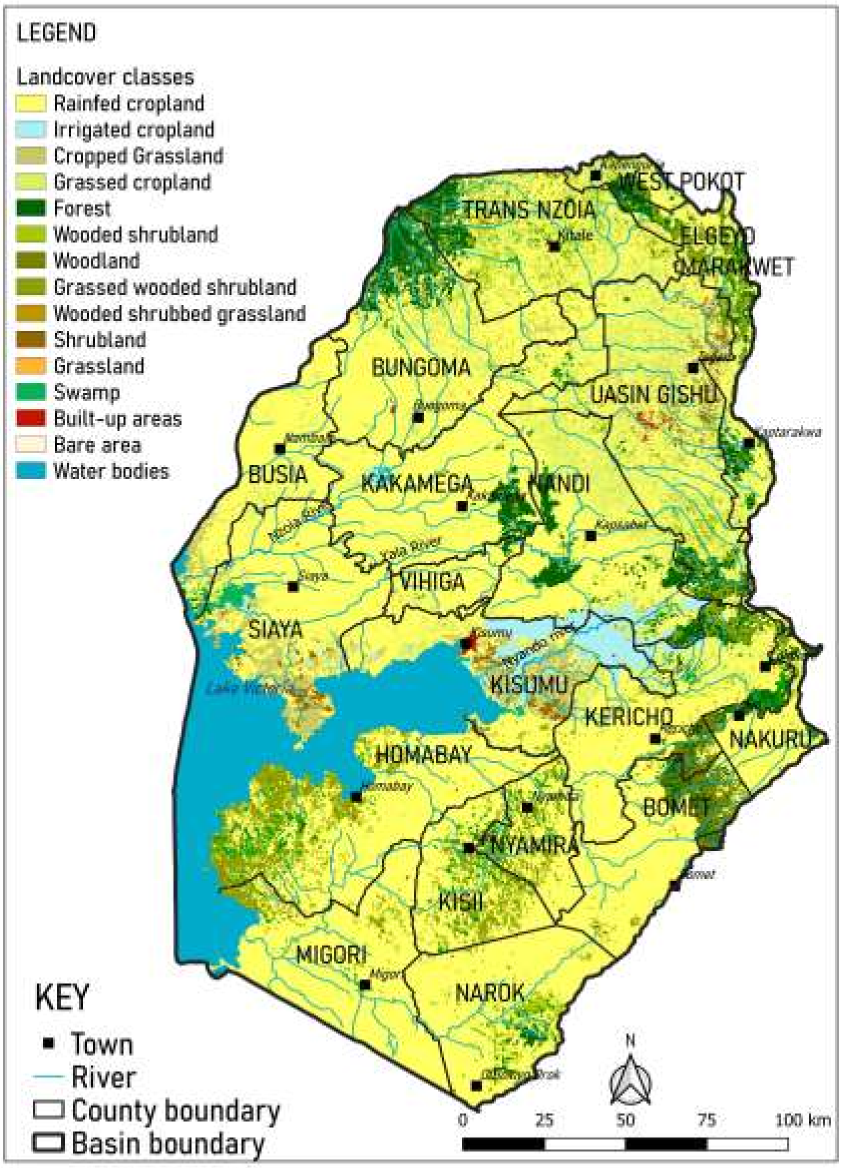


Figure 3.3: The land cover the Lake Victoria Basin of Kenya Source: Data from KALRO (2017)

## 3.8 Social and Economic Characteristics

### 3.8.1 Population in the Basin

Kenya's population is estimated to be 47 million people, with an average density of 82 persons per kilometer square and, the inter-censual growth rate of 2.2% (Government of Kenya, 2019). The Lake Victoria Basin of Kenya is estimated to have a population of over 13 million people which accounts for about 28% of total Kenya's population (Appendix II). The

Lake Victoria Basin of Kenya experiences an average population growth of 3%, something that causes pressure on limited resources. This situation is likely to magnified by increased extreme climate events caused by climate change in the area. The LVB of Kenya has a diverse community of people largely composed of Luhya, Teso, Luo, Kisii, Kuria, Maasai, Suba, and Kalenjin.

Agriculture is the backbone of most rural households' income in Basin of Kenya. The households rely on land cultivation and livestock rearing as the main primary assets for livelihoods. While the Lake Victoria Basin of Kenya can pride of many natural resources, the means to access and the power use those resources that remains a challenge that beckons a better living standard and improve one's for most households. The challenges manifest in malnutrition that is widespread, high child mortality, and protein deficiency (Mukuna, T. E. (2015). The challenges are further being accelerated by changes in climate since most of those resources are climate driven. The resources are always view in form of material, however in Lake Victoria Basin poverty of non-material resources such a decent income, capital, literacy or trained and professional skills are so profound.

### 3.8.2 Poverty and HIV/ AID Prevalence

The region has a high HIV incidences which makes the area to be one of the highly ranked globally. In the basin, the fishing sector has been documented to be the main catalyst for the traction of HIV/ AIDS. The mobility of fishermen has further engineered the spread of the disease, due frequent causual sexual relations with diverse lakeshores residents along the, on as well as those on the mainland and islands in the lake. The findings of different studies among the fishing community validated the fact that fishermen have relative advantage to cash access, fact that makes them to have a 'stronger purchasing power' for sex. (Drimie, S., Weinand, J., Gillespie, S., & Wagah, M. (2009, Akwara et al., 2003).

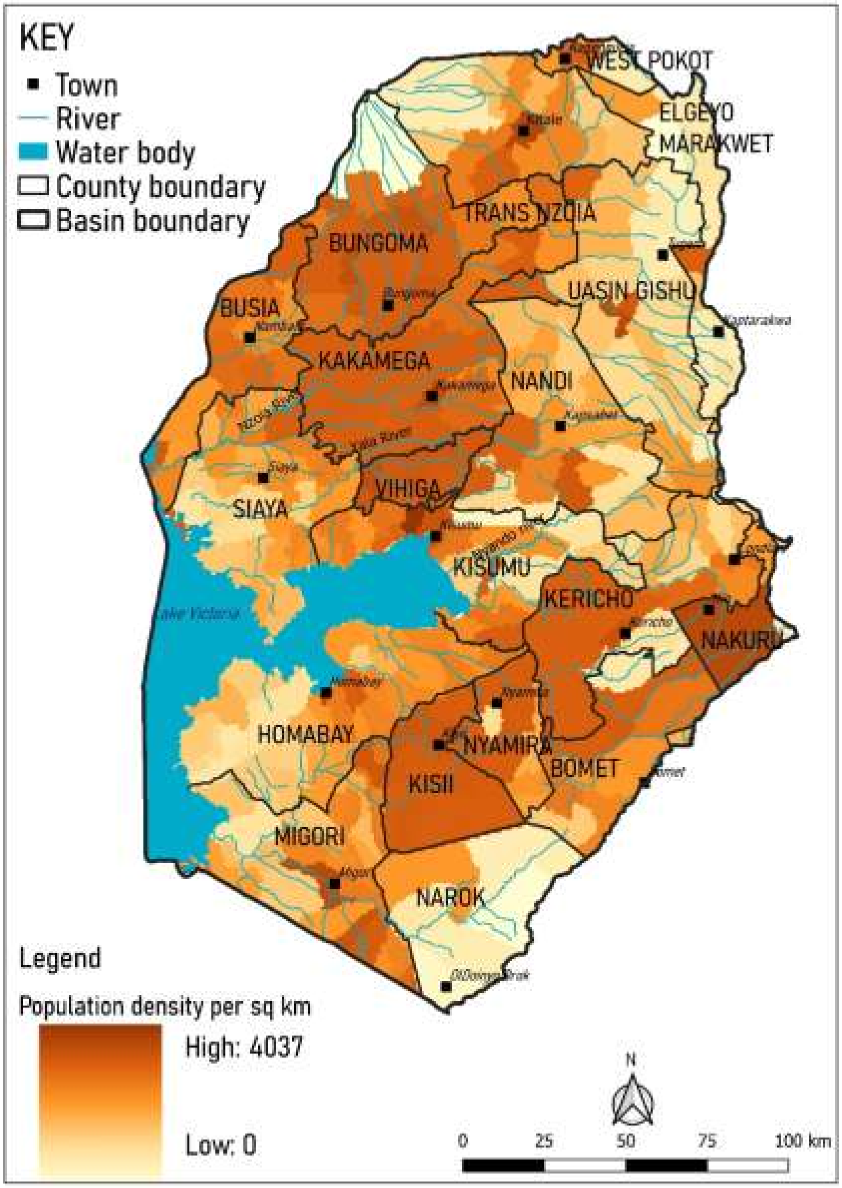


Figure 3.4: Population in the Lake Victoria Basin of Kenya Source: 2019 Census (KNBS, 2020)

### 3.8.3 Gender and Vulnerability

While it is true that men and women comprise of a vulnerable group due to climate changes, gender gap that exist women a more specific vulnerable group in the Basin. The vulnerability among the rural households in the Lake Victoria Basin of Kenya can be viewed in livelihood assets earlier discussed in chapter two. As far as households physical asset owenership are concerned, credible evidence seem to show that women more vwirulnerable owing to existance of gender related disparities. Women have lesser prospects to resource ownership and mobility compared to men within the identical social ladder. Gender inequalities in land holding is quite prevalent in the basin as described by Oxfam (2018a) that about 96% of women working in the farm, approximately 6% hold a land title. This limiting a large number women without property rights, something that men enjoy. At social and cultural aspects of vulnerability, could also be seen in other aspects such as basic human rights and access to education, governance and leadership all of which are galvanized on the social customs favour men. In the Lake Victoria Basin of Kenya, women have heavy responsibilities such as looking after and protecting the children and the ageing members of the the family. Moreover, most women tend to have minimal entrepreneurial skills, limited access to credit facilities and, their income is less secure (Scott et al., 2018).

### 3.8.4 Economic Characteristics

The Lake Victoria Basin of Kenya has favourable climatic conditions that support a number of economic activities. The vast majority of the households within the Lake Victoria Basin of Kenya depend on climate-driven resources for their livelihoods. However, agriculture and fisheries are the two most predominant livelihoods in the region (Plate 3.1 and 3.2). Agriculture mainly carried out for food crops and cash crops in some regions. The food crops grown in the Lake Victoria Basin of Kenya include maize, millet, sorghum, cassava, beans, rice, potatoes, and groundnuts. Substantial cash crops include sugarcane, tea, coffee, and cotton. Most subsistence farming is done under rainfed as the main source of soil moisture. The surplus from subsistence farming is usually sold to local markets.

Other economic activities practiced in the Lake Victoria Basin of Kenya include beekeeping, mainly in the basin's highland, trading activities, quarrying and mining of mineral such as gold in Kakamega and Migori, sand harvesting in major drainage rivers and, agro-food processing especially for sugar and tea. Increased frequency, intensity, and duration of severe climate events are likely to impact the socio-economic activities in the Basin.

In conclusion, this chapter explored the study location with specific discussions on the location and size, relief, soils, climate, drainage, vegetation characteristics, social and economic activities. In the discussions, the study indicated how the physical characteristics of the Lake Victoria basin affect its climate patterns. The chapter further discussed climate as a major propeller of the social and economic activities in the basin; thus, raising concerns about the effect of climate change at the household level.

Plate 3.1: '*Omena*' a source of livelihood in South East Location in Muhuru Ward

Plate 3.2 A farmer inspecting her vegetable farm in Kamusinga location Lake Victoria

# CHAPTER FOUR

# 4.0 RESEARCH METHODOLOGY

## 4.1 INTRODUCTION

The previous chapter examined the study area; it's location and size, relief, soils, climate, drainage, vegetation characteristics, social and economic activities and, how they relate to current study on climate change. The research methodologies employed presents the study design, data types, sources, data collection methods among others as discussed in the sections that follow.

## 4.2 Research Design

This study employed a mixed methods research approach consisting a hybrid of a longitudinal and a multi-stage sample survey research design. In longitudinal research approach, this study embraced a time-series design used for climate data while a probabilistic survey research design for household data. The time-series was ideal for this study because it was used for the extraction of climate information from historical series and prediction of future trends which are anchored on the past climate patterns. The time series analysis was also useful for this study since all the climate observations dependent on past records. In addition, the time series analysis allowed the missing climate data to be imputed. On the other hand, the survey research design ensured an in-depth description of climate change effect and adaptation measures employed by the rural household.

## 4.3 Data Types and Sources

Two datasets used in this study; secondary and primary datasets in order to achieve the objectives.

### 4.3.1 Secondary Data

The study used secondary data for rainfall and temperature, the dataset was extracted from two main sources. First, the station data was extracted from Kenya Meteorological Station headquarters at Dagoreti, Nairobi. This represented weather stations within the LVBK. Second, the gridded datasets sourced from CRU and CHIRPS. The acquired data was in spreadsheets and Common Separate Values (CSV) respectively. The weather station dataset used in this study had a base period between 1961-2016. However, since there were major gaps within the station dataset prior to 1970 (Figure 4.1), this study used a reference period between 1971- 2016 as recommended by IPCC (2007). The CRU dataset included precipitation and surface air temperature dataset retrieved from the University of East Anglia. The CRU dataset was extracted at precision of 0.5, 1.5, 2.0, 2.5 in order to attain the accuracy of Lake Victoria Basin of Kenya.

The CHIRPS dataset used in this study consisted of both weather station and in situ spatial datasets, which are mainly satellite estimations. Unlike CRU dataset, CHIRPS dataset was available in a high resolution of 0.005. Three main climate variables used demonstrate changes in climate in the study area were; mean monthly rainfall, number of rainy days, mean daily maximum and minimum temperature. The data was used to detect changes in rainfall and temperature trends and, to simulate future climate pathways in the LVBK.

### 4.3.2 Primary Data

The primary dataset was sourced from the household field survey. The data captured the following variables; the demographic characteristics, the livelihood sources, the climate effects, and household adaptation strategies. The data was sourced from the household head through a multi-stage sampling from South East, Tambua, Kamusinga, and Twiga locations, all representing four main agro-climatic zones in the Basin. The household data addressed two research objectives, one on the climate change effect on household livelihood and the other on the household adaptation strategies. The secondary data from Kenya Population and Housing Census 2009 inter census report was used to determine the household target population and sample size.

## 4.4 Data Collection

### 4.4.1 Pilot Survey

This study conducted a small preliminary survey to evaluate the feasibility, cost, and potential complication of carrying out climatology research in the LVBK. The researcher placed an order for climate data to the Kenya Meteorological Department headquarters at Dagoreti, for the list of all the weather stations with the long length of climate observation. The aim was to underpin the number of weather stations with long record of quality climate data for credible results. The preliminary study involved acquiring a list of weather stations and their length of data records for the purpose of a preliminary analysis to determine the quality and consistency. At total of forty-seven weather stations with climate data was provided my availed.

The pilot study also involved testing the questionnaire as a way of ensuring that it was comprehensible and appropriate in capturing essential variables. A total of eighty questionnaire were administered household heads to drawn from Tambau and South East location in Vihiga and Migori Counties respectively. The main reasons for pre-testing the questionnaire was to decide whether or not to exclude or modify (rephrase) some of the questions. The preliminary analysis of the questionnaire administered ensured that only final questionnaire has only relevant and appropriately phrased questions to be put to the interviewees from the main sample.

### 4.4.2 Target Population

The target population for climate data included, all the operational weather stations within the Lake Victoria Basin of Kenya, which had good spatial representation for different agro-climatic zones. Furthermore, the identified weather stations had to have a long data observation record for an in-depth climate analysis. On the basis of the above description, a total of 47 weather stations (Appendix III) constituted the target population. While for the household to constitute a target population, the household must have been rural in nature, must have lived within the basin for period not less than thirty years and their main livelihood activities must revolve around climate driven resources such as smallholders farming. On the basis on these descriptions, a total of 5,407 households from four main agro-climatic zone of the Basin constituted the target population.

### 4.4.3 Sampling and Sample Size

All the operational weather stations in Lake Victoria Basin of Kenya (see appendix III) constituted the climate dataset sampling frame. From the sampling frame, only weather stations with the consistency of data records over 30 years, and their geographic representation of selected agro-climatic zones were selected. On that basis, purposive sampling was used to select fourteen weather stations (Table 4.1).

Table 4.1: The Selected Weather Stations

| No | Number | Name of Weather Station | Latitude | Longitude | Altitude | Opened |
|---|---|---|---|---|---|---|
| 1. | 9034025 | Kisumu Met. Station | -0.1 | 34.75 | 1130.7 | 1938 |
| 2. | 8933026 | Port Victoria Catholic Mission | 0.12 | 33.98 | 1230 | 1939 |
| 3. | 8934096 | Kakamega Agromet Station | 0.28 | 34.77 | 1530 | 1957 |
| 4. | 8934106 | Bukembe | 0.62 | 34.67 | 1438 | 1998 |
| 5. | 8934098 | Kimilili Forest Station | 0.87 | 34.68 | 1650 | 1959 |
| 6. | 8834098 | Kitale Meteorological Station | 1.02 | 34.98 | 1875 | 1950 |
| 7. | 9034088 | Kisii Meteorological Station | -0.68 | 34.78 | 1740 | 1962 |
| 8. | 8935010 | Kaptagat Forest Station | 0.43 | 35.50 | 2200 | 1928 |
| 9. | 8934016 | Lugari Forest Station | 0.66 | 34.90 | 1590 | 1932 |
| 10. | 8934061 | Malava Agric. Station. | 0.45 | 34.85 | 1560 | 1940 |
| 11. | 8934023 | Sang'alo Institute Station | 0.53 | 34.58 | 1372 | 1933 |
| 12. | 9035003 | Kericho Met Station | -0.383 | 35.28 | 2184 | 1904 |
| 13. | 9035229 | Sabatia Forest Station | -0.05 | 35.75 | 1740 | 1958 |
| 14. | 9134009 | Muhuru Hydromet. Station | 0.99 | 34.09 | 1200 | 1939 |

Source: Kenya Meteorological Department (2017)

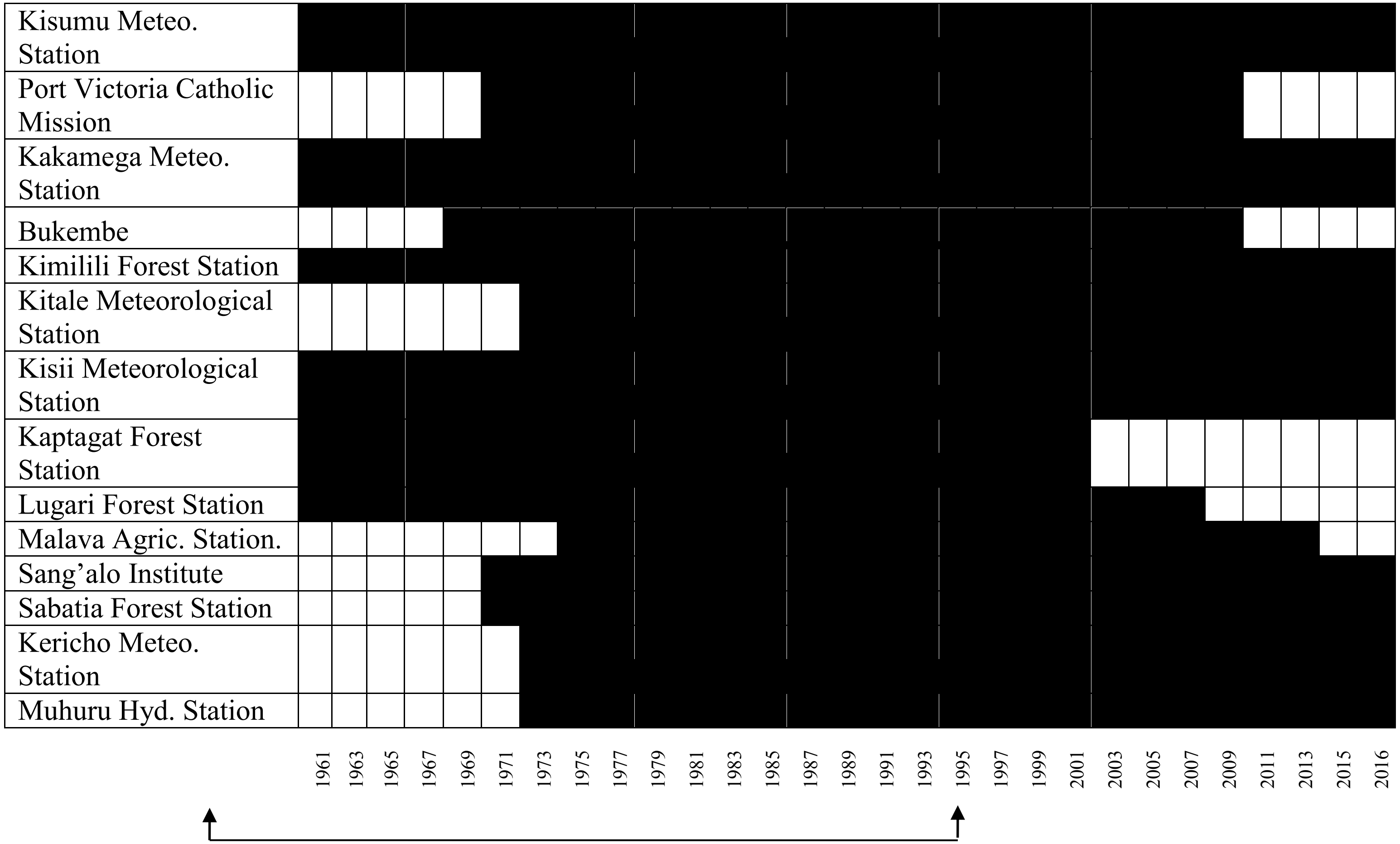


Figure 4.1: Rainfall Observation Period Source: Kenya Meteorological Department (2017)

To ensure adequate spatial representation of household data in the LVB of Kenya, the four main agro-ecological zones namely: the lower midland; the upper midland; the lower highland and upper highland were first mapped out using arcGIS software, to show the areal extent of the zone. The layers of administrative units; counties, sub counties, wards and locations were then overlayed on the ecological zones for easy visual analysis, hence the spatial representation. Using the multi-stage sampling, four administrative locations were considered for the study. In the lower midland zone, South East location; the upper middle, Tambua Ward; the lower highland zone, Kamusinga location and Twiga location as the upper highland, were respectively selected (Table 4.2).

## Table 4.2: Household Survey Study Sites

| Agro-ecological zone | County | Sub- County | Ward Selected for study Site | No. of household | Gin index |
|---|---|---|---|---|---|
| Lower Midland | Migori | Nyatike | Muhuru | 4,669 | 0.426 |
| Upper midland | Vihiga | Hamisi | Tambua | 4,007 | 0.348 |
| Lower Highland | Bungoma | Kimilili | Kibingei | 6,460 | 0.343 |
| Upper Highland | Trans Nzoia | Endebes | Chepchoina | 1,865 | 0.288 |

Source: Government of Kenya, 2019

The household participants were however drawn from a multi stage sampling from four selected administrative locations; South East, Kamusinga, Tambua, and Twiga. To ensure validity and consistency, a 10% of each the targeted household population from four administrative locations was considered.

**Table 4.3: Distribution of a Sample Size**

| Agro-ecological zone | Selected Ward for Study | Selected Study location | Location Households size | No. of Selected Households |
|---|---|---|---|---|
| Lower Midland | Muhuru | South East | 1,320 | 132 |
| Upper midland | Tambua | Tambua | 1,253 | 125 |
| Lower Highland | Kibingei | Kamusinga | 1,639 | 163 |
| Upper Highland | Chepchoina | Twiga | 1,195 | 119 |
| | | **Total** | **5,407** | **539** |

Source: Government of Kenya, 2019

### 4.4.4 Instruments for Data Collection

Primary data on the household livelihoods were collected using a household questionnaire (Appendix IV). Additional data was collected from a semi -structured interviews for key informants using (Appendix V). The questionnaire consisted of both closed and open-ended questions consisting of three sections; section one gathered demographic information about the respondents, section two had questions on climate effect on the household, while section three had questions on the household adaption strategies. The use of household questionnaire permitted a wide area coverage and extensive contents adequate for review and consistent with the research objectives. The questionnaire was administered by the researcher and a team of trained field assistants (Plate, 4.1, 4.2).

Plate 4.1: Researcher collecting data from a coffee farmer in Twiga location as source of livelihood, Tran Nzoia

Plate 4.2: A researcher administering a household questionnaire to a household in Kamusinga location, Bungoma

A standardized interview schedule was used to probe for more details on the key informants' views and opinions on climate change indicators in the region and potential effect on households. The key informants were drawn from sub county officials, extension officers and elderly people in respective locations. The probing was further captured using a digital voice recorder (Plate 4.3). Mapping of the area of study was done using Garmin GPS device (Plate 4.6). An observation method was further used to document physical items that were of interest to the study.


Plate 4.3: Sony Digital Voice Recorder

Plate 4.5: Computer and internet Storage


Plate 4.4: Transcend External Hard drive


Plate 4.6: Garmin GPS Receiver

### 4.4.5 Procedure of Data Collection

In order to obtain necessary climatic data, a shapefile containing the study area was presented to the KMD headquarters in Dagoreti with a request to extract the list of all the existing weather stations in the LVB of Kenya. The identified weather stations were mapped to ensure the spatial representation of various agro-climatic regions. The station data in the spreadsheet was collected in order to validate gridded data and corrected the missing data as well as computing monthly and annual data. Daily minimum and maximum temperatures were also collected to compute for daily temperature ranges as well as monthly mean temperature. The collected data was stored in an external hard disk (Plate 4.4), computer local hard disk and Internet saving (Plate 4.5). In the external hard disk, each station was considered a file, where a year was considered a variable for the study. Other secondary climate datasets from CRU and CHIRPS were retrieved from ICPAC in the common separate values.

## 4.5 Data Processing and Analysis Techniques

The weather station data and spatial data acquired in form of excel spreadsheets and common Separate Values (CSV) respectively were formatted in a way that was easy to work with and understand. The three days observed rainfall weather station data extracted for all the years were summed up, while temperature data were averaged into months. The monthly climate data was then transposed to form years; each year was saved in the external hard drive as a weather data file.

The climate data collected were subject to quality control and homogeneity test (Peterson et al., 1998; Zhang et al., 2009). The checks were to confirm the consistency, validity and reliability in the data. The errors in the data were checked using ISTAT+ version 3.36, to spot data gaps between 1961- 2016. Any station data that had lower than 10% of missing were selected for the study. However, to resolve the problem of missing datasets in selected stations that had lower than 10%, this study used two ways to sort out the missing gaps. First, the stations which had lower than 5% missing data, computed arithmetic mean was used to estimate the missing values but only if it was without extreme values. Where the extreme values were present in the data, the median was employed to ascertain the missing data. The second approach was where the values were completely missing. Those values were estimated using the Inter-station correlation formula provided by the World Meteorological Organization as shown below:

$$X = \frac{X_n X_m}{X_n}$$

--------------------------------------------------------Formula 1

Where:

**$X_m$** rainfall estimates for a specific month at precise station,

**$X_n$** rainfall observed for the above specified month at a neighbouring station,

**$X_m$** rainfall average for a station with missing data record but highly correlates with the precise station;

**Xn** rainfall average at the neighbouring weather station.

**m** & **n** are the record length for stations that has missing data in relation to neighbouring weather station.

Some human errors were also noticed such as negative rainfall data records, the minimum temperature that was greater than maximum temperature; and mean daily the temperature which was greater than maximum temperatures. The error checks helped to eliminate erroneous values and the missing data records were correlated with synoptic data sourced from both CRU and CHIRPS data records for the same baseline period of 1971-2016.

After having ensured quality control checks, the climate data was subjected to homogeneity test using RH-test software, used in previous climate studies to detect changes in mean climate data series (Wang et al., 2007) and to detect extremes changes in precipitation and temperature (Aguilar et al., 2005). The expected the result was to show a straight line if the data was homogeneous. The least squares regression analysis was used to identify homogeneities and, a two-tailed t-test was used to examine statistical significance. Any deviation from the straight line meant that the rainfall data was not consistent in the record and this could be attributed to changing the station's environment or the change in recording instruments.

The manipulation and extraction of data from the external hard disk required conversion into one format spreadsheet for Windows 2007 computer software. The functionality of this conversion was available in one computing language the Java, which made it possible for the climate data to be directly integrated into R codes ready for analysis.

The household data collected using the questionnaire and a standardized interview schedule was first processed using an elaborative procedure as follows; verification of data, preparation of codebook, data mining so as to investigate error, data entry, verification of data entry, complete entry, coding raw data, correct raw data file, identification of inconsistencies in data, cleaning of data proceeds if there are no inconsistencies, final back-up of data, data manipulation was initiated which proceeded to data pre-analysis (Figure 4.2) before being subjected to data analysis. The raw data from copies of filled in questionnaires and standardized interview schedule was received by the researcher for verification. After verification, the researcher prepared a codebook, which was used as a guide in data mining. In data mining, the researcher was able to uncover the errors in the raw data, hence further verification for completeness and consistency in data. The process was followed up by coding data into SPSS IBM version 23. Further cleaning was done to ensure consistency and accuracy in the data. The cleaned data was then saved on a computer/ Internet storage and external hard disk for data manipulation and data pre-analysis.

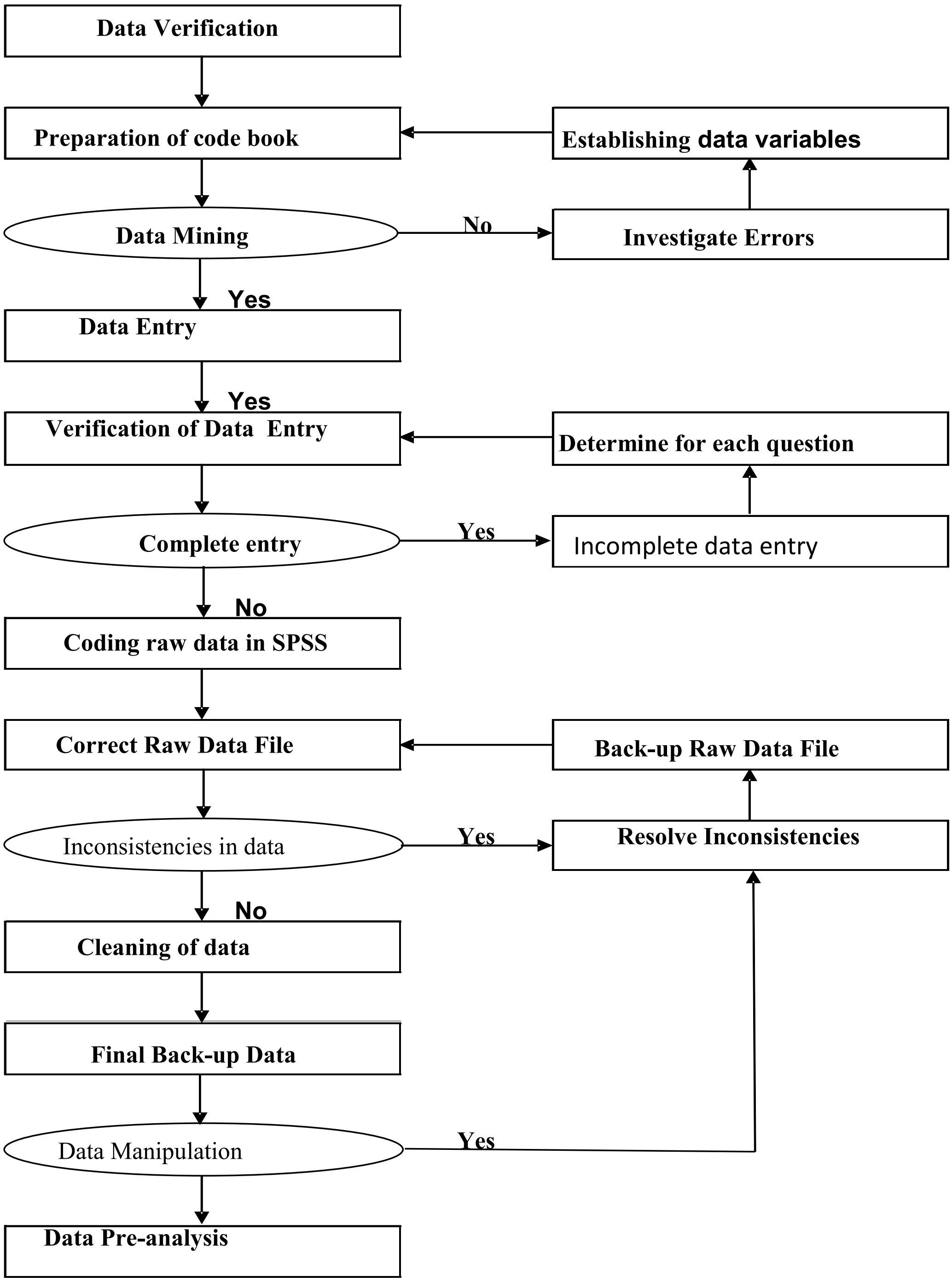


Figure 4.2: Household Data Processing Procedure Source:Resercher 2020

### 4.5.3 Data Analysis Techniques

#### 4.5.3.1 Climate Data

The climate datasets collected were subjected to various statistical analysis techniques, using R-Language and Environment for Statistical Computing software (R core Team, 2018). The software had functions that enabled the data to be manipulated, compute estimates and to display the results in the graphical form. The software was considered vital for current study because it was easy to acquire, it was effective in handling large climate data collected for this study, its functional tools were for easy for data analysis and, it facilitated the graphical representation of data for easy analysis.

Each weather station record was subjected to analysis with the aim of exploring the existence of trends. The climatological monthly mean plots were used to establish the rainfall characteristics over the basin. The trend analysis for annual rainfall was established using long term monthly mean rainfall. This was considered important for this study since it helped in time series analysis of wetness and dryness.

Each observation data record was subjected to time series analysis with the intention of discovering the trends. The climatological monthly mean plots were used to examine annual rainfall distribution for designated weather stations. The plots revealed the rainfall regimes over the Lake Victoria Basin of Kenya. The annual rainfall trends were computed using monthly average rainfall. The existence of a trends in the data was deemed to have an effect on the basic statistics of the data or the other aspects of the time series. This was believed to be vital for this study especially in the analysis of hydrologic conditions of the Lake Victoria Basin of Kenya.

The extent of hydrologic conditions over the Lake Victoria Basin of Kenya was established using Standardized Precipitation Index (SPI) for the duration between the 1987- 2016 period for all the chosen weather stations and therefore the result conferred to quantity the entire basin. The analysis was done at 3 and 12-month time scale as proposed by WMO (2012) (Table 4.4) The three- and twelve-months scales of SPI index were thought to be vital in understanding the effect of rainfall on rainfed agriculture that is preponderantly practiced within the Lake Victoria Basin of Kenya. The three-month the scale though, shorter time scale was applicable to the current study once factoring the rainfed agriculture which relies on soil moisture availability whereas, the twelve months' scale was found to be important in establishing on rural livelihoods.

### Table 4.4: Standardized Precipitation Index Classification Criteria

| | SPI index Value | Condition |
|---|---|---|
| 1 | 2.0+ | extremely wet |
| 2 | 1.5 to 1.99 | very wet |
| 3 | 1.0 to 1.49 | moderately wet |
| 4 | -.99 to .99 | near normal |
| 5 | -1.0 to -1.49 | moderately dry |
| 6 | -1.5 to -1.99 | severely dry |
| 7 | -2 and less | extremely dry |

Source: WMO, 2012

The spatial analysis was done by establishing the rainfall and temperature mean distribution and Co-efficient of Variation. For rainfall data, coefficient of variation was analyzed in all the seasons for the all the years under investigation. The Mann-Kendall test was used to examine the presence of trends in climate dataset. The annual rainfall and sum of rainy days were used to explore general trends. The Mann-Kendall test has previously used in similar studies by Ongoma et al. (2018). The Liebmann et al. (2012) method was applied to determine to computed the onset and cessation of rains for the period of study. It was necessary first compute the daily accumulative rainfall anomaly for any specific day using the equation shown below:

$$C(d) = \sum_{j=1\,jan}^{d} Q_i - \bar{Q}$$
-------------------------------------------------Formula 2

Where;

**C(d)** refers to daily accumulative rainfall anomaly

**Qi** refers to the calendar year (first January to thirty first December)

**Q** refers to a climatological rainfall mean,

**i** varied from 1st January to day **(d)** for which applied computing.

The dates for rainfall onsets and cessations were calculated independently for respective year by means of the equation below:

$$A(D) = \sum_{j=ds1-20}^{d} R_j - \bar{Q}$$
----------------------------------------------Formula 3

Where;

**A(D)** referes to cumulative daily rainfall

$\mathbf{R_j}$ refers to rainfall on the day **j** and j extended from $\mathbf{d_s}$ **-20**.

A(D) was calculated for respective day $\mathbf{d_s}$ **-20 to** $\mathbf{d_e}$ **+ 20** and for individual year $\mathbf{d_{s2}}$ **-20 to** $\mathbf{d_{e2}}$ **+ 20**

The day subsequent the minimum A(D) was translated to an onset date, while cessation date happened after the maximum both seasons.

To quantify signals changes in climate the optimal fingerprinting technique of detection was used as recommended by Paeth & Mannig (2012). The computation of standard deviation was further used to check the extreme climate events at 95% confidence level. The standard deviations value ± 2 was used and any that was outside that value was considered exceptional. The Time Series Technique was the most appropriate tool to be used in the study. It was available in the SPSS IBM version 23 and this necessitated the use of data query functions in SPSS to import the excel data files. In addition, extreme value statistics was applied to focus on severe drought and flood events using appropriate extreme value distribution, such as the Generalized Pareto distribution (Paeth, H., & Hense, A. 2005).

Frequency analysis was also used to compare the climate change challenges to their frequency of occurrence through the probability distribution. The extreme values from the probability distribution were fitted to the available data using the method of probability weighted moments. To give the actual picture of the rainfall distribution of each month during the study period, a more sophisticated statistical technique was necessary. The CORDEX Regional Climate model was used for climate change simulation at three-time scales; near, mid and far future. An understanding of a hydrologic year at those time scales was vital in the planning and management of human livelihood. In climatology study, a hydrologic year is better understood in the context of identifying rainfall onsets and cessations of any given region. Liebmann et al. (2012) successfully used the technique to identify onsets and cessation over entire Africa was first done. The technique was further adopted by Boyard-Micheau et al (2013) and Camberlin et al (2009) to investigate the hydrologic year in East Africa. In both studies, there was sufficient evidence to show that the use of Gridded Daily Observation Datasets obtained from the CHIRPS and Stations realized a reliable finding (Funk et al., 2015). This particular study deployed the same technique to identify the onsets and cessations over Lake Victoria. An onset was considered to be the wet first day (of one mm and or above) for a single or two successive days adding up to the minimum of twenty mm rains without any seven day period of dry spell which totals to below five mm) throughout the twenty subsequent days. When conditions are reversed, it was considered to be a cessation.

#### 4.5.3.1.1 The CORDEX Regional Climate Models

The model was developed and managed by the Rossby Centre Atmosphere. CORDEX is Regional Circulation Model version 4 (RCA4) which runs as the numerical weather prediction model (Unden et al., 2002). The RCA4 has a slight improvement from the previous version 3, RCA3 (Samuelsson et al., 2011). The model is an output from six downscaled Global Climate Models (Appendix VII). The GCMs provide appropriate appraisal tools for changes in climate in different regions. These models, however, have a low spatial resolution of between 100-250 km, so low that it limits the simulation capability of a small area such as LVB of Kenya. A downscaled version, the CORDEX Regional Climate models (hereafter referred to as CORDEX RCMs) is well articulated by Nikulin et al. (2012). The models originated from the World Climate Research Program, under the ambit of WMO. The models form a state of art regional climate simulation, which comprises of a dynamic ensemble group of models that were initiated for high-resolution Regional Climate projection of 50 km (Giorgi et al., 2009). Since its establishment, the models have been used to simulate the climate in the Great Horn of Africa (Ogallo et al., 2018). In the simulation, CORDEX RCMs were found to be suitable tools for studying regional climate change.

The study further identifies different versions of CORDEX RCMs (Favre et al., 2011). The CORDEX RCMs are designed to simulate the climate that covers an area between 16°S - 18°N, 22° - 52°E, which is further divided into the three sub-regions, classified on the basis of the rainfall distributions, which include Northern East Africa, Southern East Africa, and Eastern East Africa. This study relied on the latter, which is located between 2.25° - 11.75°N, 44.25° - 51.75°E, whose performance was found to accurately simulate regional rainfall climatology of the region (Endris et al., 2013).

The application of CORDEX RCMs to this study has some advantages, it is customized, and CORDEX RCMs Eastern Africa provides a spatial resolution useful for an understanding of the local climate within the entire region LVB. CORDEX RCMs has the capability of simulating complex topography its interactions with climate forcing that affects the spatial climate patterns similar to that which is experienced in the LVB (Alley et al., 2007). CORDEX RCMs have a fine grid resolution, which is able to simulate extreme rainfall that is capable of causing foods and dry seasons that have the potential of being considered droughts. Whereas several strengths of models have been discussed, available literature (Giorgi et al., 2009) indicated that the ensemble climate models of CORDEX tended to over simulate rainfall in some regions; this study, however, addressed this limitation by using the ensemble mean and correlating with observed station data.

**4.5.3.1.2 Validation of the CORDEX Models**

The study used the technique proposed by Gleckler et al. (2008), as a standard for diagnosing fit of climate models. In the technique, the models were summarized objectively so as to rank them based on their misfit (error). The outputs of models were summarized by their correlation with the observation (Figure 4.3).

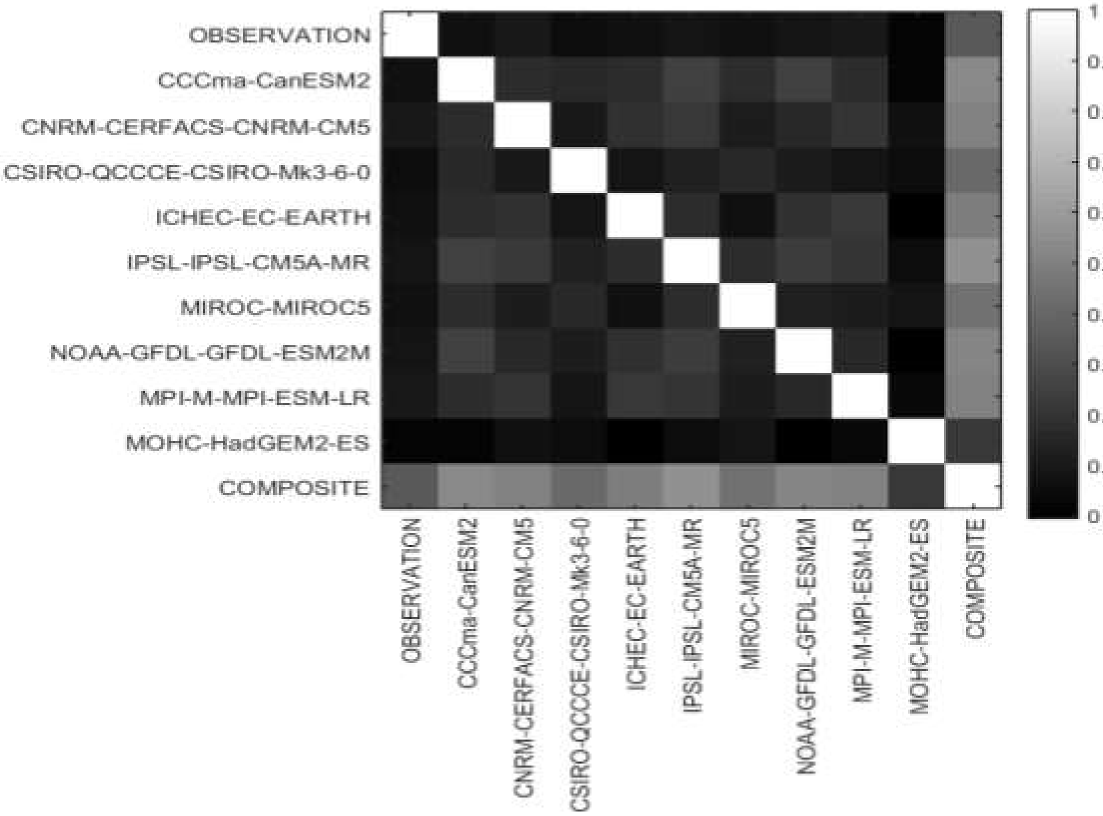


Figure 4.3: Heat map showing correlation relationships between the observed daily rainfall over Kisii Meteorological station, and estimations from the nine different GCMs

The result from Figure 4.3 was generated by correlating the daily observation data (from CHIRPS data) with the corresponding historical climate model data from the different models at Kisii Meteorological station. It was observed from the study that the correlations were barely 0.5 between the models and the observation. However, the average of all the models (composite) reached 0.5, the composite of the model was established as the best estimator for future climate projection. Heat maps from model tests for other selected stations from the Lake Victoria Basin of Kenya had the resemblance.

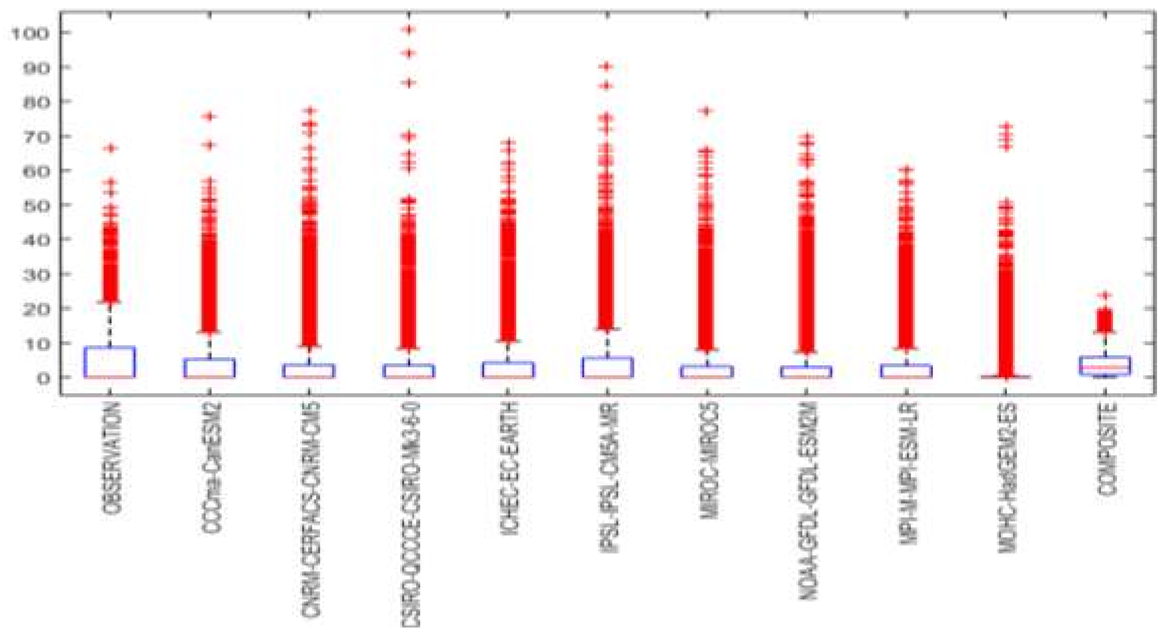


Figure 4.4: Box and whisker plots showing the daily rainfall values spread in the dataset

These plots were used to investigate statistical properties of the data and data comparison (Banacos, 2011). They show the central tendency and dispersion of the data, including the extreme values (outliers). From the analysis, the outliers are described as the values occurring lower or higher than 1.5*IQR (Inter-quartile range, that is, the range between the 75$^{th}$ and the 25$^{th}$ percentiles). The outliers are indicated by the red stars above the whiskers (Ts emanating from the boxes). The daily rainfall values had a median value of zero (red line), therefore, the observations were basically zero as well that of the models, the composite seemed to spread values to points of zero model realizations such that its median was slightly higher than zero (Figure 4.4). The climate models had many outliers (notably the CSIRO Mk3.6.0 model). However, the composite of all the climate models reduces those outliers and represent the observations better in terms of the correlation coefficient.

**4.5.3.2 Household Data Analysis Techniques**

Upon the completion of households data collection, the raw data was first categorized in four groups depending on the point of collection. The household data from South East, Tambua, Kamusinga and Twiga were thus considered for further analysis procedure. All the copies of questionnaires bearing raw data were then numbered and cleaned. Further scrutiny was done to ensure completeness, accuracy, and consistency of information with other in-depth interviews and observation.

The data collected on the current climate change effect as well as the adaptation strategies were grouped into themes in accordance with research objectives where they were both analyzed quantitatively and qualitatively. The collected data was analyzed using mixture of descriptive statistics and some nonparametric inferential statistics. In the descriptive statistical analysis, the data was summarized to capture information about variables. The statistical analysis tools such as the mean, standard deviation, minimum, and maximum and variances were to compute variables. The frequency in the dataset was also analyzed to obtain the demographic characteristics of household heads. The Cross tabulations another statistical tool used in this stud to investigate on demographic information related with either effect of climate changes on the rural livelihood or adaptation strategies employed by the households in the Lake Victoria Basin of Kenya. The crosstabulation analysis tool therefore provided several vantage points of observing household datasets.

In the inferential Statistical analysis, the Chi-square test was used measure the level of independence between household demographic data and the effects of changes in climate and, adaptation strategies at household level.

The logistic regression model was used to investigate the effect of changes in climate on rural household livelihood The logistic regression models use the maximum likelihood method to estimate the coefficients of our regressors on the dependent variable reporting the logit-transformed probability as a linear relationship with the outcome variables and are formally expressed as follows:

$$logit(p) = log\left(\frac{p}{1-p}\right) = \beta_0 + \beta_1 x_1 + \cdots + \beta_k x_k$$

-----------------------------Formula 4

Where $\beta_0$ is the constant, $\beta_1$ is the coefficient of interest for the stringency index, and $\beta_2, \beta_3, \ldots, \beta_k$ refered to a coefficients vector corresponding to the control variables. The control variables includes various climate shocks, gender of household head, and livelihood activities for the regression looking at rural livelihood sources, and other variables such as the gender of the household head, crop production, livestock production, energy and water sources.

The specification can be reordered to obtain the predicted probability of outcome as follows:

$$p = \frac{e^{\beta_0 + \beta_1 x_1 + \cdots + \beta_k x_k}}{1 + e^{\beta_0 + \beta_1 x_1 + \cdots + \beta_k x_k}}$$

---------------------------------Formula 5

In this logistic regression model, the outcome variable is binary with 1 representing those households that self-reported that climate change severely affected them and 0 otherwise.

The independent variables were control factors (including Location and Sex of the household head) while the other variables are livelihood based (participation in the mentioned livelihoods).

**4.6 Ethical Consideration**

In ensuring that ethical consideration was upheld in the course of this study, first, the letter from the Department of Geography and Environmental Studies at the University of Nairobi was obtained. Upon the submission of the letter and a copy of the approved proposal, a research permit was issued by the National Commission of Science and Technology and Innovation (NACOSTI) (see Appendix 1). The relevant authorities in all the sampled Wards were presented with the research permit for the research to be conducted in line with research regulations contained in the research permit.

This study ensured that the agreed-upon standards for research ethics are maintained at all levels. For the primary data involving households, the researcher and the field assistants openly considered the needs and concerns of the people in the study area. They also ensured that an appropriate basis for trust was established between the researcher, research assistants and study participants by ensuring that respondents were adequately informed and their consent sought for the purpose of the data being collected. No inducements of whatever kind were given to encourage participants to participate in the study, and there were no risks attached to the process. Confidentiality was maintained throughout this study, where necessary, anonymity and confidentiality of household participants' disclosures were also ensured.

In brief, the research methodology section discussed among other subtopics; the study design, data types, and sources, data collection methods, target population, sampling procedure and sample size, and data processing and analysis techniques employed in the study. The chapter further, validated the use of CORDEX model in simulating regional climate. It also explored the ethical issued considered in this study.

# CHAPTER FIVE

## 5.0 RESULTS AND DISCUSSIONS

### 5.1 Introduction

The section details the study findings, offers context and discusses the results in four sub-sections guided by the research objectives. The first sub-section discussed the spatio-temporal characteristic rainfall and temperature indices, the second sub-section addressed the climate change effects on the rural livelihood, the third sub-section discussed the household adaptation strategies and, the last sub-section discussed the potential future climate pathways.

### 5.2 The Spatio-Temporal Characteristics of Rainfall and Temperature

The study findings of the study revealed that the Lake Victoria Basin of Kenya is fairly warm and rainy across the whole year. The region has four distinct rainfall regimes: Jan & Feb (JF); Mar-May (hereafter referred to as Mar -May), June, July & Sep (hereafter referred to as JJS), and Oct- Dec (hereafter referred to as Oct-Dec) seasons (Figure 5.1). The aggregate mean for climate data in the selected weather stations depicted a bimodal rainfall season Mar-May and Oct- Dec rains. Findings for individual weather stations also depicted the two main rainy seasons (Appendix VI). The result confirms that previous finding by Anyah & Qiu (2012).

The Mar -May rain peaks in the month of April, while the Oct-Dec rains peaks around November. Ogallo's (1988) study established that this particular season account for 42% of the annual total rainfall, account for 25%. The Jan-Feb (JF) rains were mostly observed from the stations closer to the Lake Victoria, while June-July-August-September (JJAS) were mostly observed in the basin's highland. The previous study in the same region indicated Jan-Feb rains were attributed to the location of ITCZ and the moisture influx around the lake (Indeje et al., 2000).

From the study findings, a downward trend was depicted for the Mar -May rains and an increase in the Oct-Dec rains was observed. The variability in Mar -May and Oct-Dec could probably be used to explain rainfall variation earlier established by Kizza, et al. (2009).

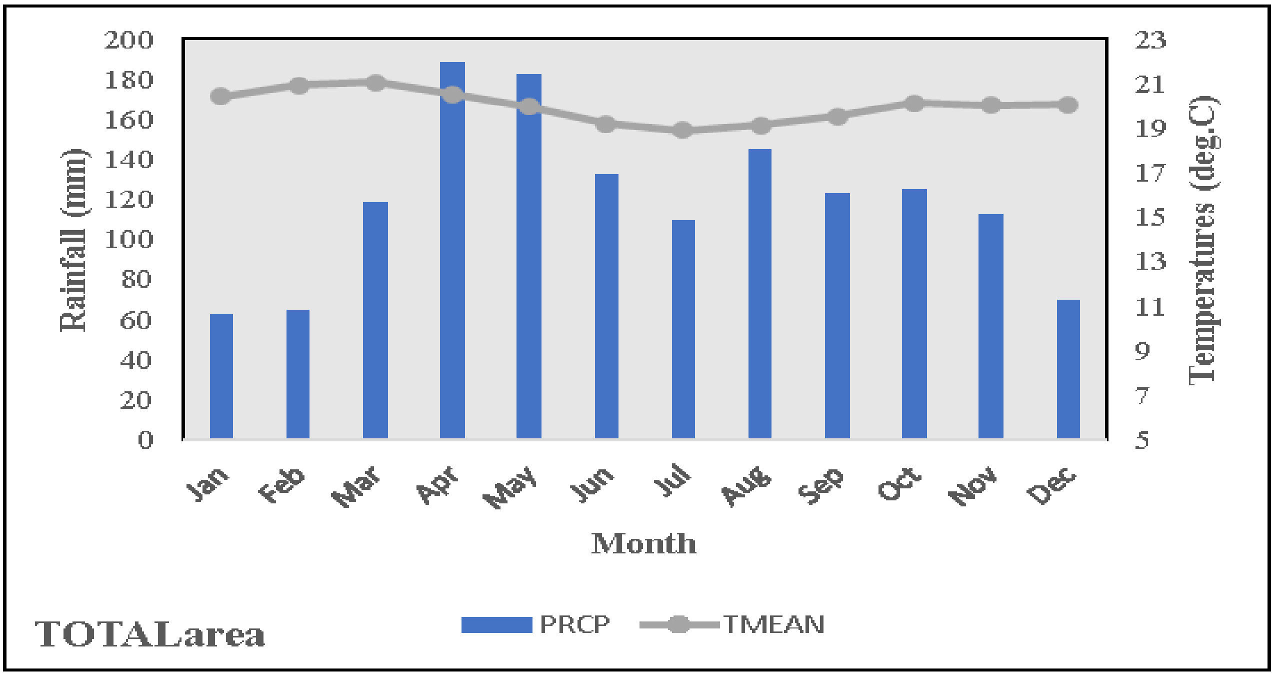


Figure 5.1: The Rainfall and Temperature Regimes Lake Victoria Basin of Kenya's

The further analysis of on the component of a time series, an increasing linear trend was observed for average annual rainfall over the Lake Victoria Basin of Kenya for a period between 1971- 2016 (Figure 5.2). Near decadal re-occurrence of significantly high rainfall was recorded in the late 1970s, 1980s and 1990s, a clear indication of ten year return period. The pattern return period has since been shortening between mid-2000 to 2016. A significantly high rainfall was also accompanied by significantly low average annual rainfall in the years early 1980s, 1990s and early 2000s. From the seasonality component a regular predictable average annual rainfall changes that re-occur in a regular interval was observed. However, a short-term average rainfall fluctuation in the seasonality was revealed in the seasonality of annual rainfall between the years 1971- 2016. These fluctuations captured as random component experienced significantly high annual rainfall in the years 1997,207 and have since become common after the year 2010 (Figure 5.2).

The results of time series analysis further revealed an increasing trend in average temperature in the Lake Victoria basin between 1971-2016, as depicted by trend line (Figure 5.2). The increase was however non-linear. The seasonality component of average annual temperature displayed a regular change that re-occurred in a regular interval. A short-term fluctuation in the seasonal average annual temperature were also observed. The fluctuations were not systematic and available data could not predict re-occurrence (Figure 5.2).

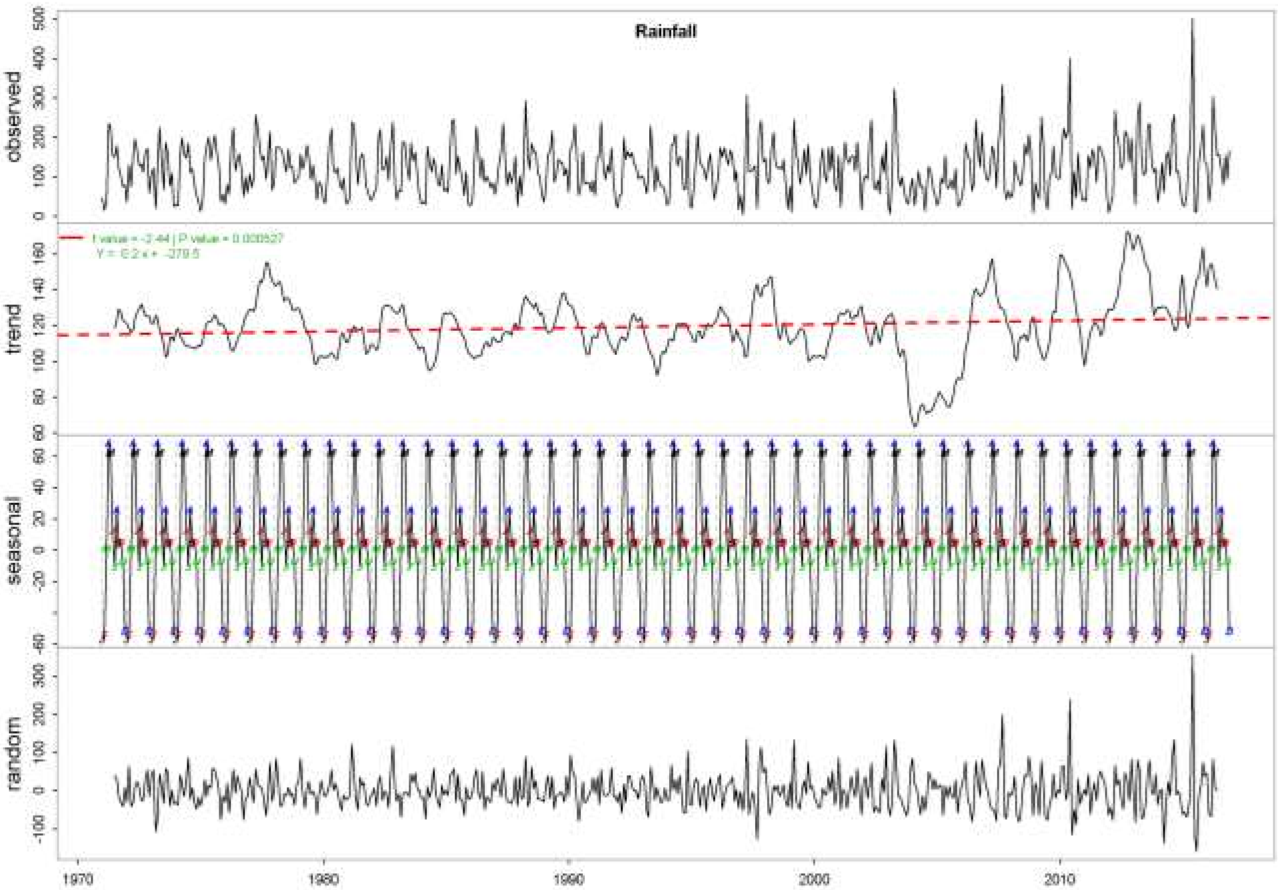


Figure 5.2: Components of the time series for averaged rainfall over the LVBK

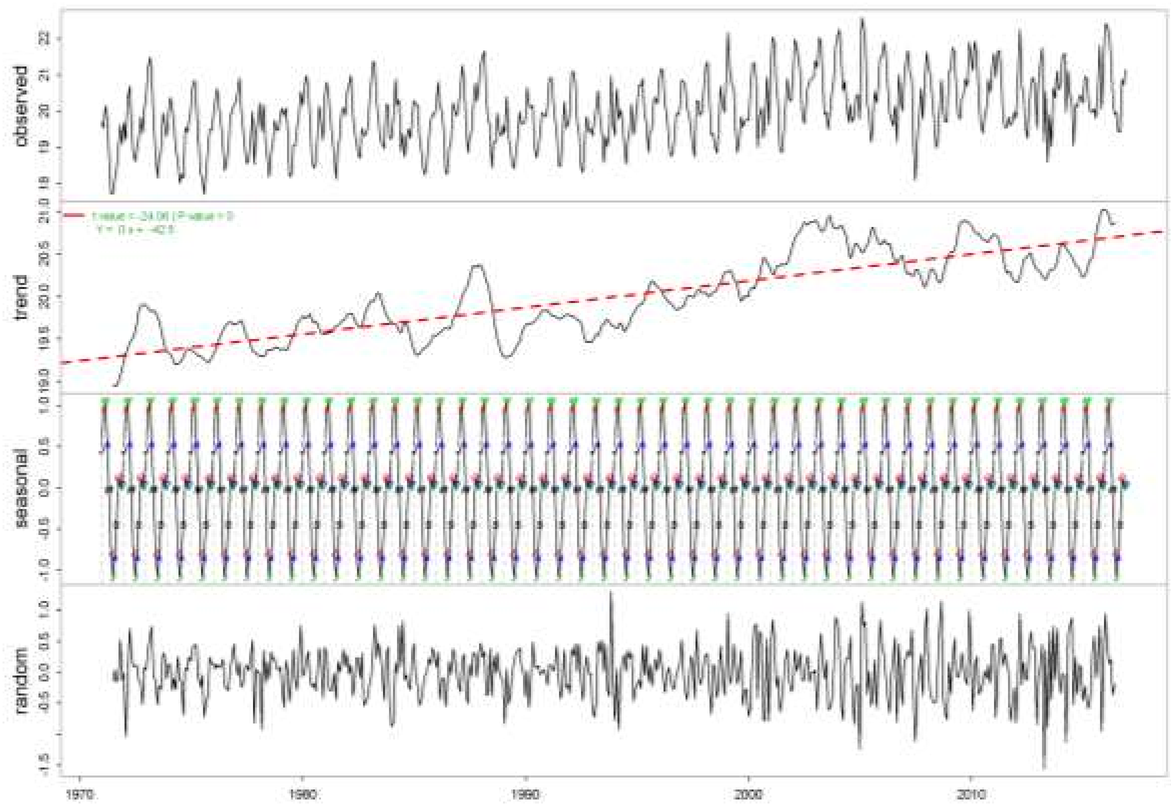

Figure 5.3: Components of the time series for mean monthly temperature data over the Lake Victoria Basin of Kenya

### 5.2.1 Characterization of Meteorological Drought over the Basin

The findings revealed several years with categories of wet rainfall and dry conditions. Recent years, 2009- 2016, recorded more wet conditions. However, the normal wet conditions have declined as captured in Figure 5.4. The wetness and dryness in the Lake Victoria Basin of Kenya had no clear trend. The computation of SPI values on the twelve months scale, however, revealed that the years between 2009 to 2015 experienced an extremely wet category of rainfall, while years closer to 2004 to 2007 which exhibited minimal changes in extremely dry conditions (Figure 5.5). The twelve months scale was therefore used to confirm the outputs observed for less than 3 months' scale for the same climatological period (1987 - 2016).

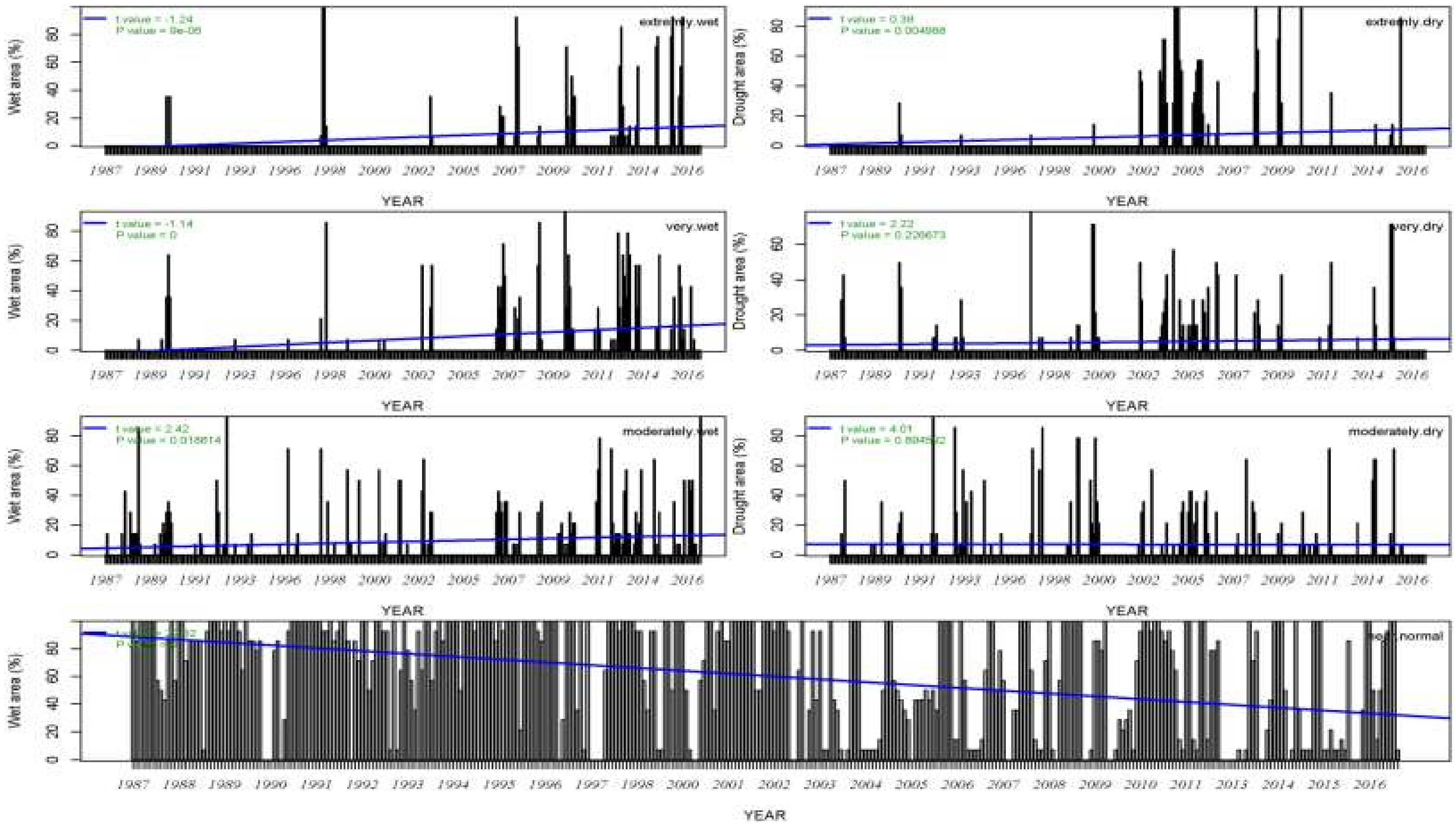

Figure 5.4: SPI Graphical Illustration for three-month scale for the Selected weather stations over the Lake Victoria Basin of Kenya

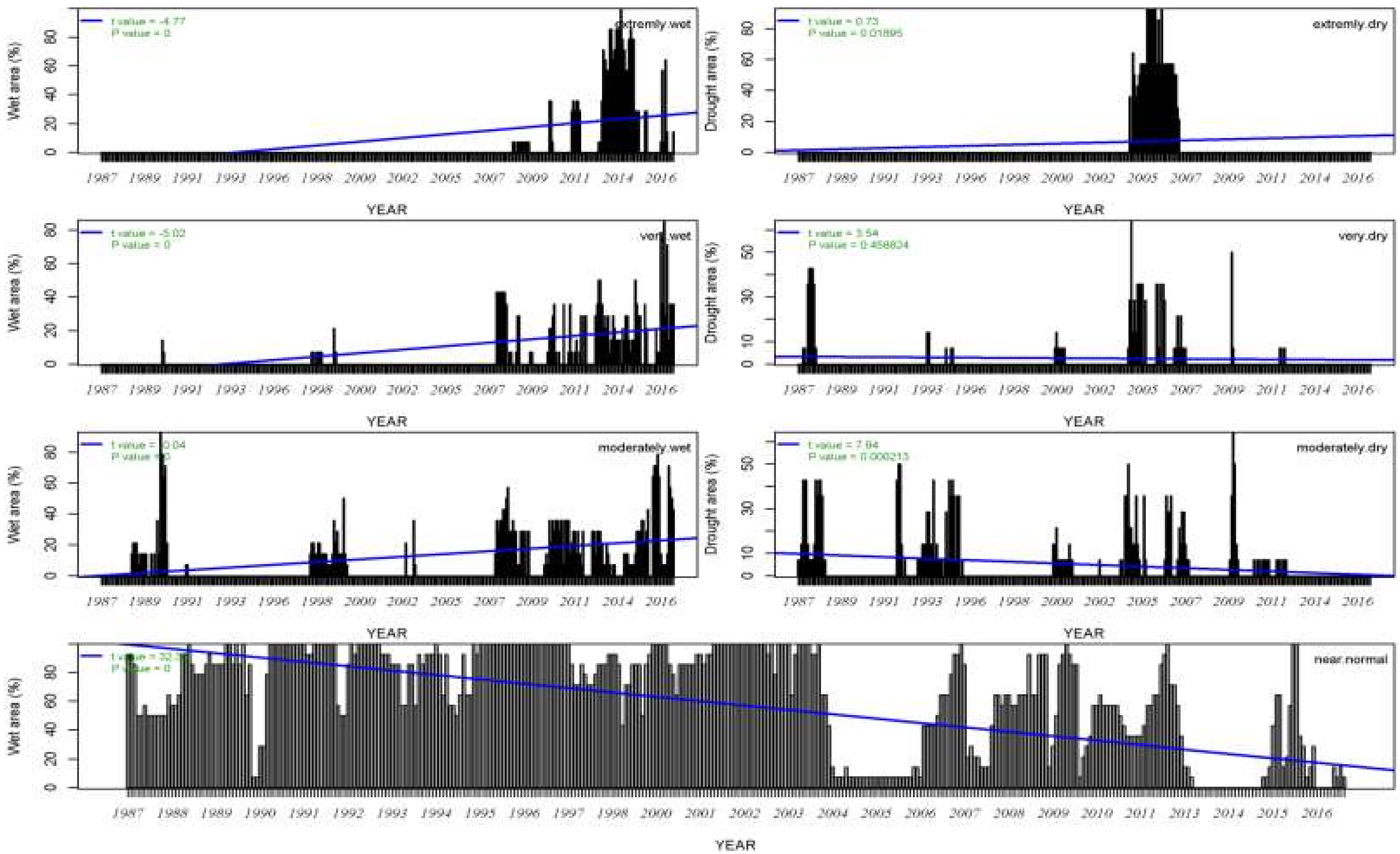


Figure 5.5: SPI Graphical Illustration for twelve-month scale for the Selected weather stations over the Basin

### 5.2.3 Seasonal Trends Analysis

The study finding revealed an increase of about 0.5ºC - 0.7ºC in minimum temperatures (Figure 5.6), and 0.7ºC - 0.9ºC in maximum temperature (Figure 5.7) respectively was observed at Lower Midland Zone Hydromet Station. The observation was between January and December for the two distinct climate regimes 1957-1986 and 1987-2016. The ratio between standard deviation and the mean minimum temperature exhibited a change in the variability, while the mean maximum temperature indicated no change in the maximum temperature (Figure 5.8). The ratio between the rainfall mean and standard deviation exposed a downward trend of Mar-May rains and a rise in Oct-Dec rains. A comparison of the coefficient of variabilities in the two distinct climate regimes (1957-1986 and 1987-2016) increased variability in the short rains (Oct-Dec season) was observed.

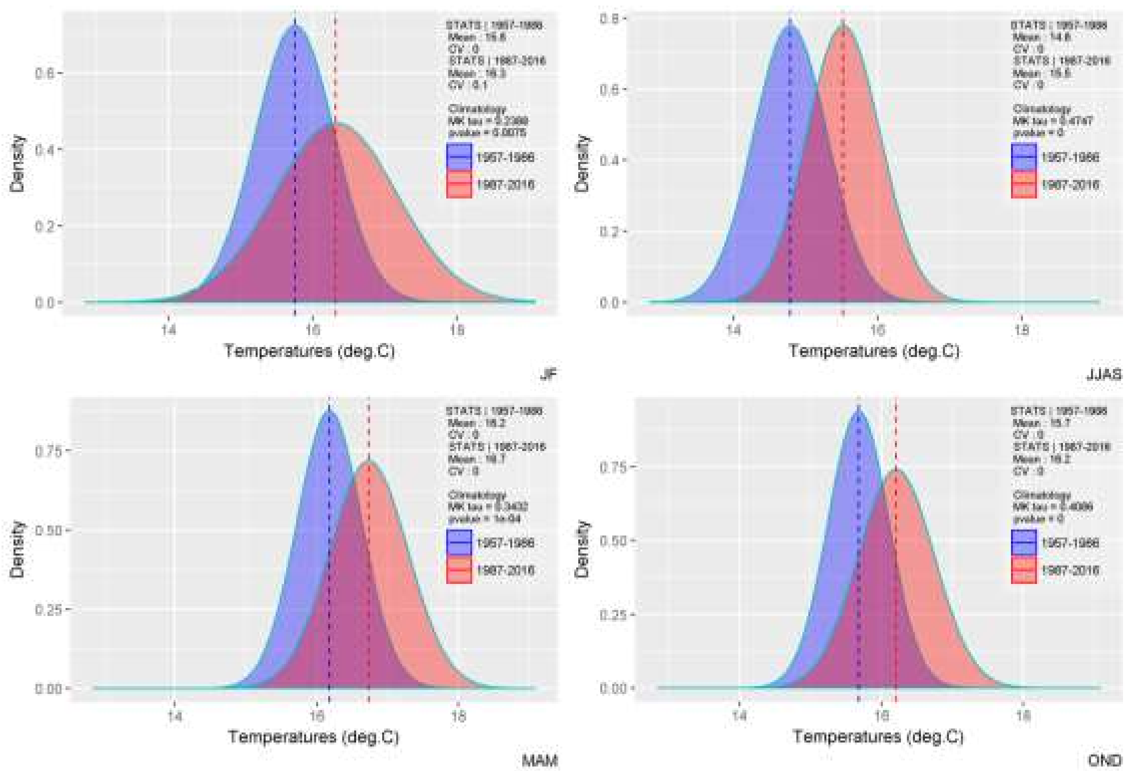


Figure 5.6: Minimum temperatures distribution plots for period between (1957-1986) and (1987-2016) over Muhuru Bay Hydromet Station.

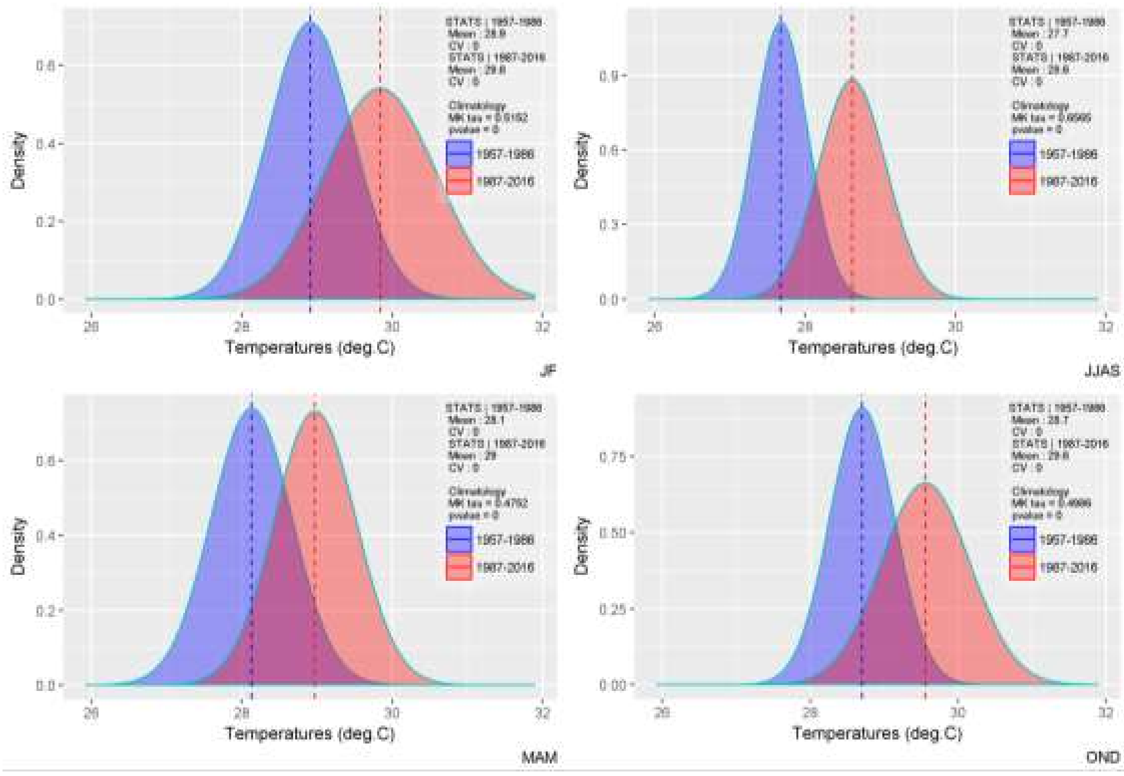


Figure 5.7: Maximum temperatures distribution plots for Muhuru Bay Hydromet Station for period between 1957-1986 and 1987-2016.

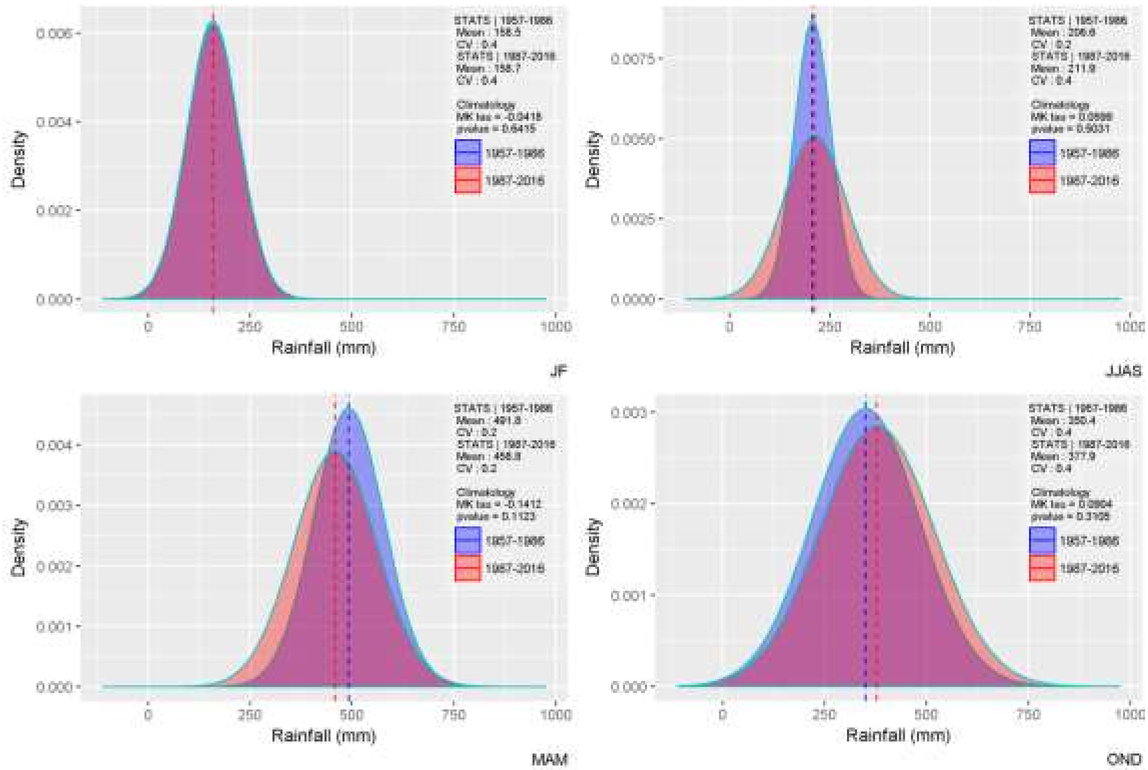


Figure 5.8: Rainfall distribution plots for Muhuru Bay Hydromet Station for period between 1957-1986 and 1987-2016.

A cold season was observed between June - September at Sabatia Forest Station. The ratio of standard deviation and the mean of the minimum temperature for the entire years exhibited changes in the minimum temperature of about 0.6ºC - 08ºC (Figure 5.9) and about 0.8ºC - 09ºC for maximum temperatures (Figure 5.10) was observed. The study finding revealed a declining trend in the mean rainfall for Mar -May rains and a small margin increased variability in the short rains (Oct-Dec season) for 1986-2016 period (Figure 5.11).

5.2.3.1 Analysis of Variabilities in Climate Parameters at Sabatia Forest Station

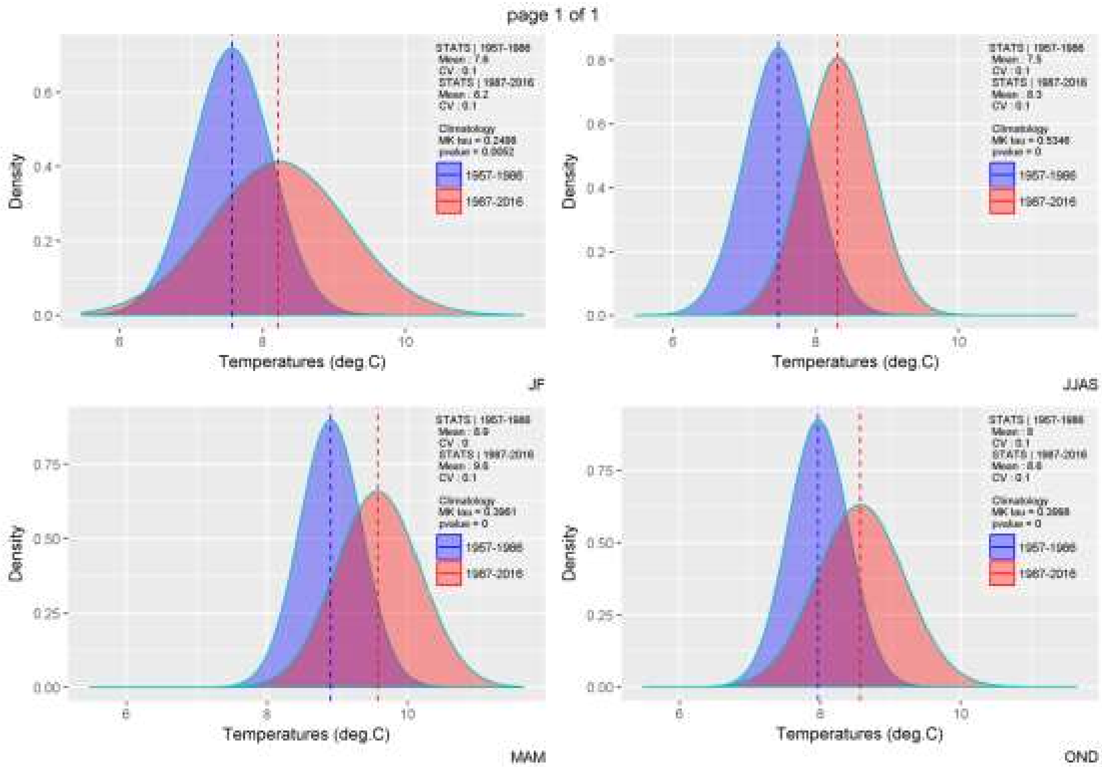


Figure 5.9: Minimum temperatures distribution plots for Sabatia Forest Station for period between 1957-1986 and 1987-2016.

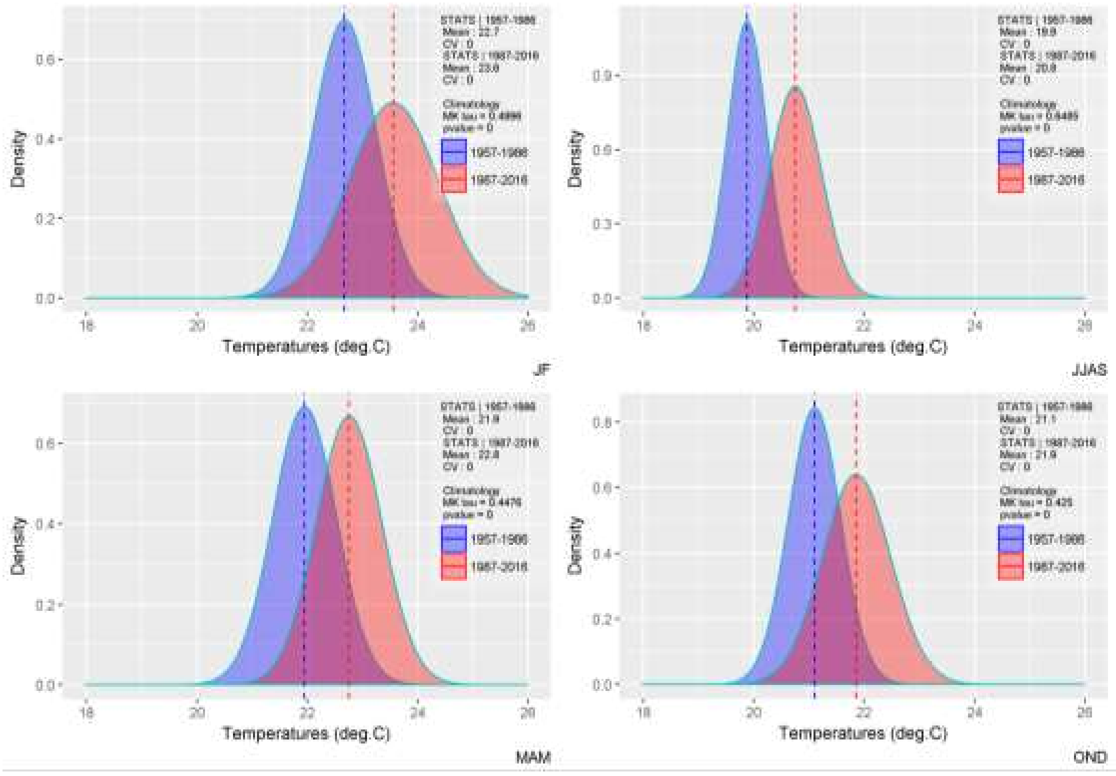


Figure 5.10: Maximum temperatures distribution plots for Sabatia Forest Station for period between 1957-1986 and 1987-2016.

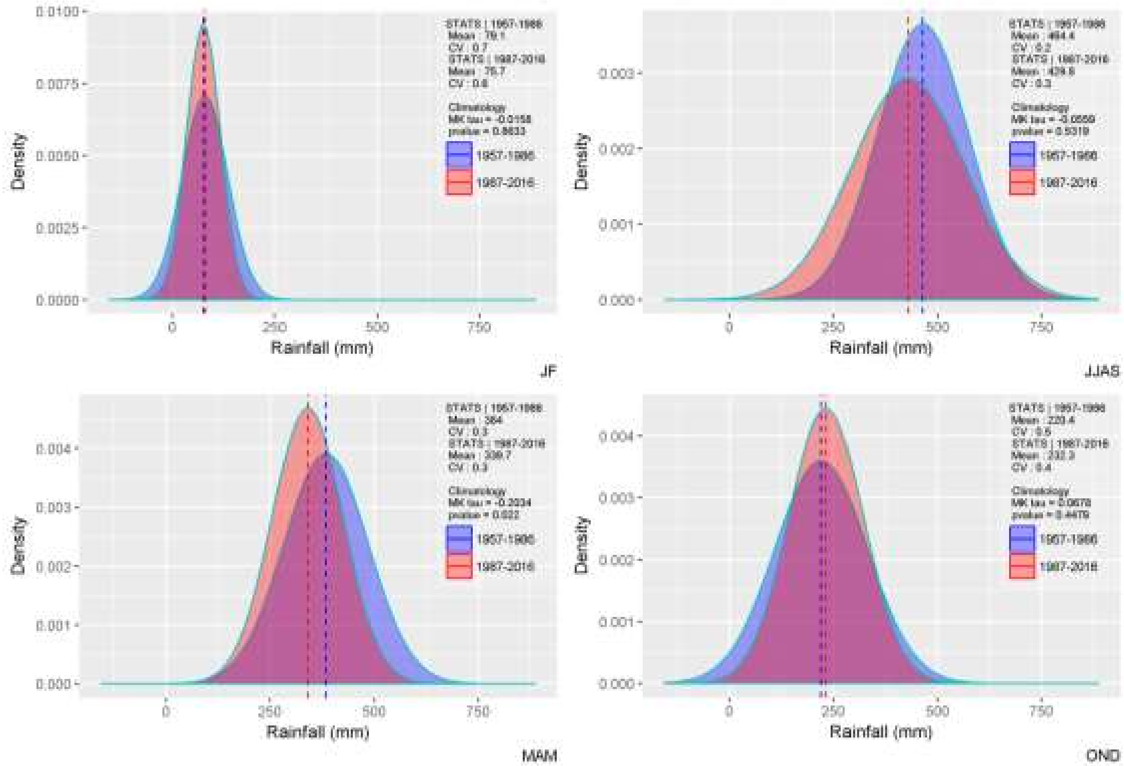


Figure 5.11: Rainfall Distribution plots for Sabatia Forest Station for period between 1957-1986 and 1987-2016.

In Kericho Metrological station, it was observed that June to September (JJAS) was the coldest season. The ratio of standard deviation and the mean minimum temperature exhibited a change of about 0.7ºC- 09ºC for the 1987 - 2016 period (Figure 5.12). Changes in the mean maximum temperature of about 0.8ºC- 0.9ºC were also recorded in the same period (Figure 5.13). There were no changes in variability detected in the maximum temperature. The ratio of standard deviation and the mean rainfall exposed a downward trend in Mar -May rains and an upward trend in Oct-Dec rains (Figure 5.14).

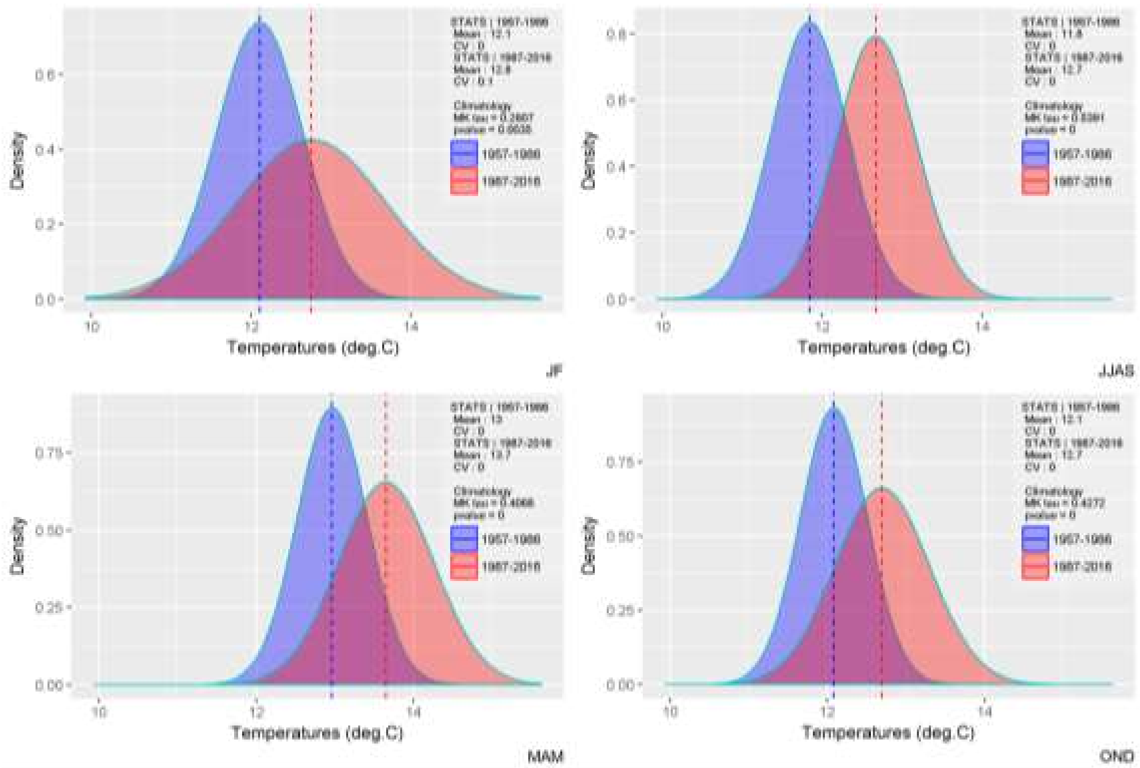


Figure 5.12: Minimum temperatures distribution plots for Kericho Meteorological Station for period between 1957-1986 and 1987-2016.

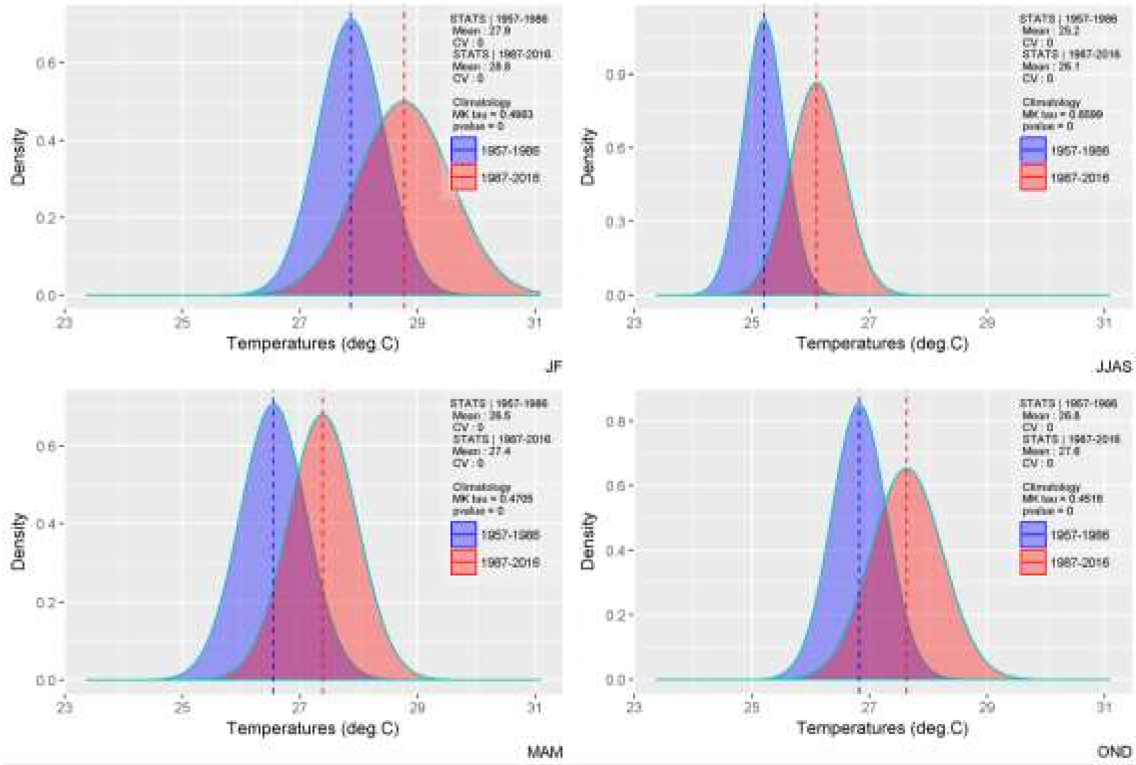


Figure 5.13: Maximum temperatures Distribution plots over Kericho Meteorological Station for period between 1957-1986 and 1987-2016.

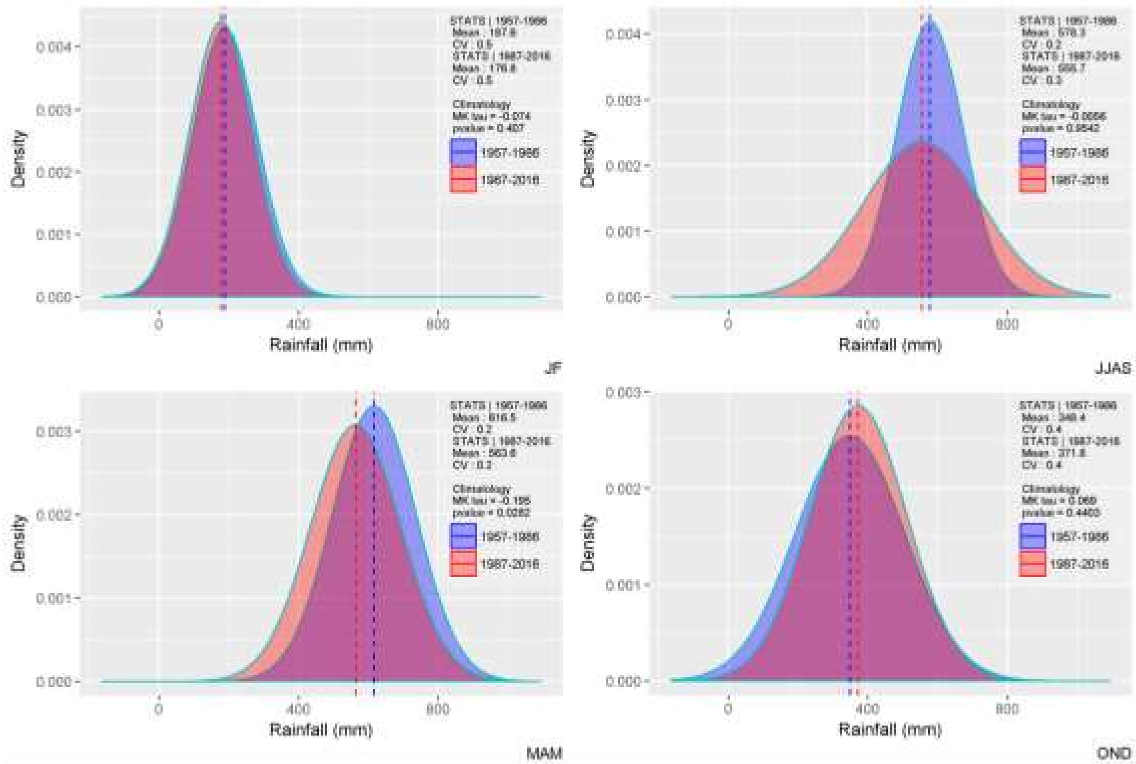


Figure 5.14: Rainfall distribution plots over Kericho Meteorological Station for period between 1957-1986 and 1987-2016.

At Sang'alo Institute Station, the study finding showed an increase of about 0.6ºC - 0.9ºC in the mean of minimum temperature between 1987 - 2016 climate period (Figure 5.15). The mean of maximum temperatures recorded an increasing trend of about 0.8ºC - 1ºC for the same climate period. The same trend was observed from the mean of maximum temperatures (Figure 5.16). The study finding showed a decline in Mar -Mat rains, an increase in Oct-Dec rains, and an increase in the 1986-2016 period (Figure 5.17).

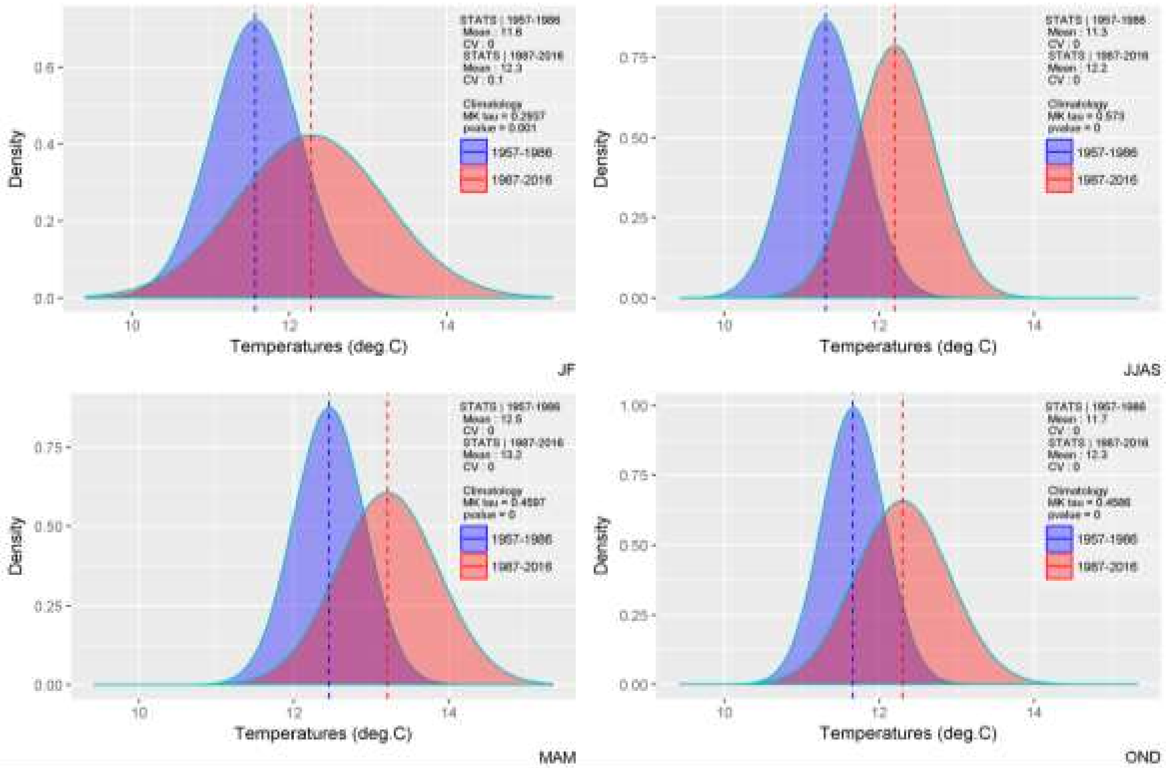


Figure 5.15: Minimum temperatures distribution plots for Sang'alo Institute Station for period between 1957-1986 and 1987-2016.

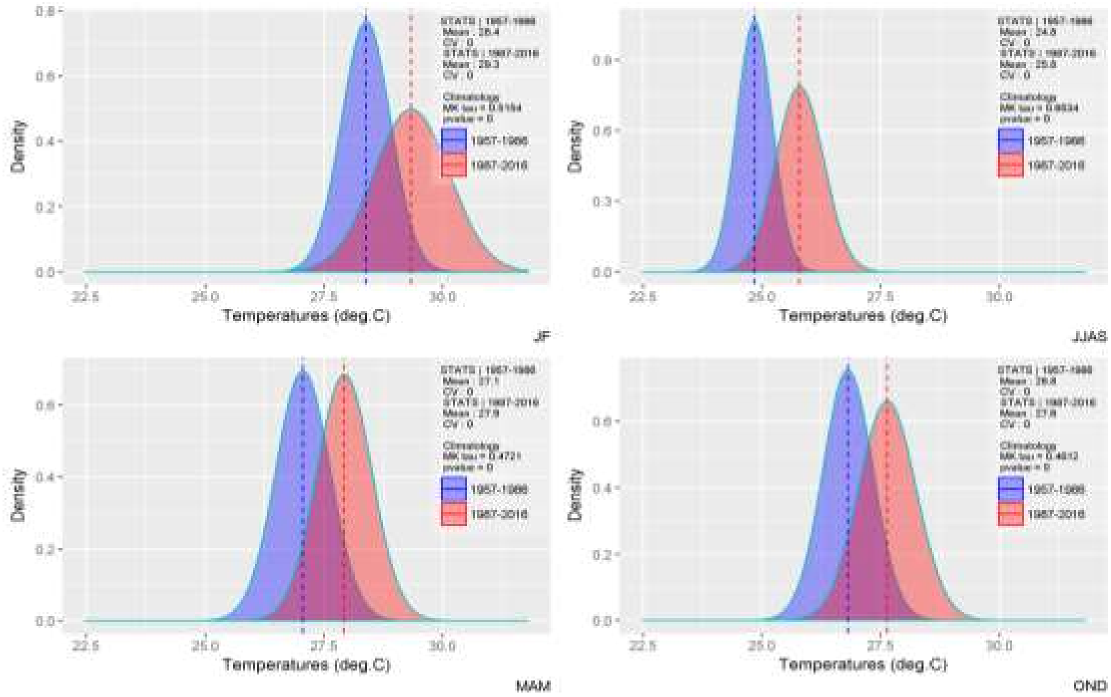


Figure 5.16: Maximum temperatures distribution plots for Sang'alo Institute Station for period between 1957-1986 and 1987-2016.

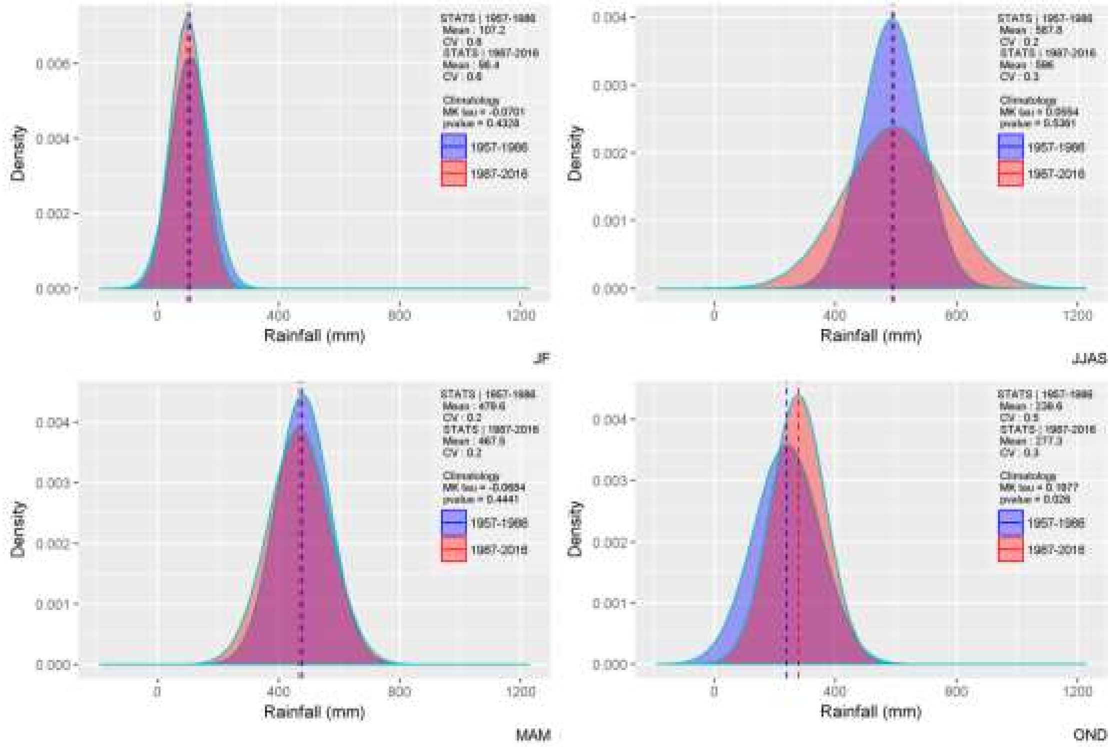


Figure 5.17: Rainfall distribution plots for Sang'alo Institute Station for period between 1957-1986 and 1987-2016.

At Malava Agricultural Station, it was established that the JF season was the warmest (Figure

5.18). There was sufficient evidence to show a minimum temperature increase which ranged between 0.8ºC to 1ºC while the mean of maximum temperature had increased between 0.7ºC - 0.9ºC for the same period (Figure 5.19). The Mar-May rains recorded a downward trend while OCT-DEC rains upward trend was observed. In the two distinct climate regimes (1957-1986 and 1987-2016), increased variability in Mar -May rains was observed (Figure 5.20).

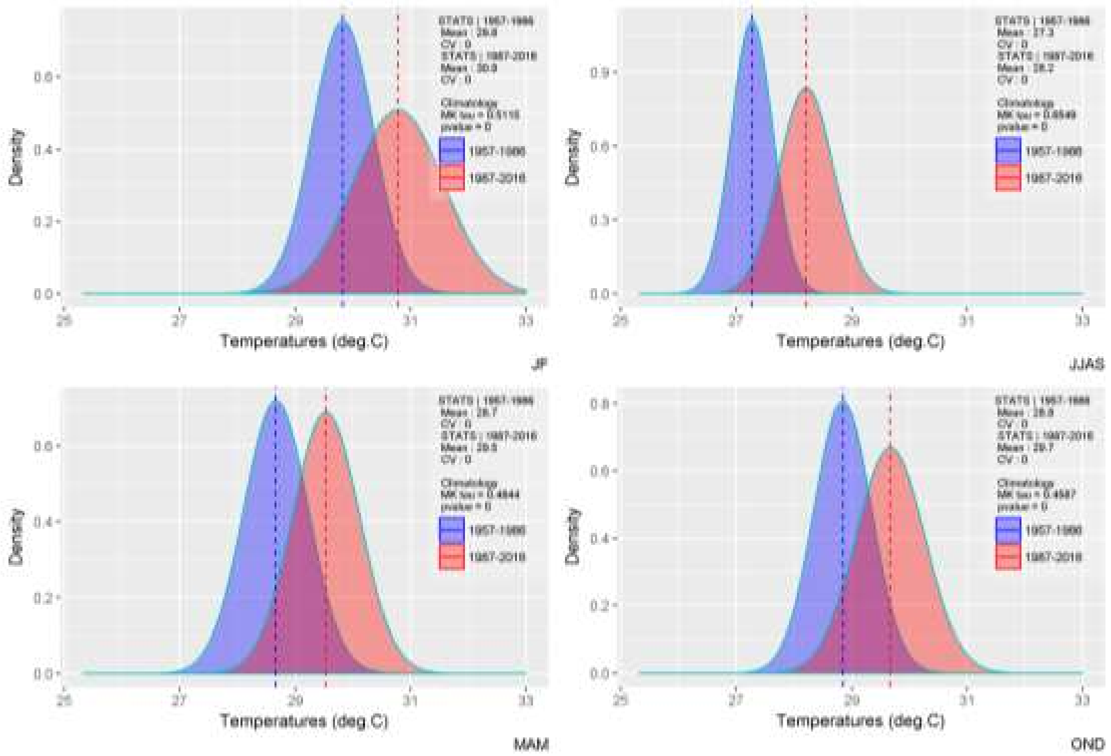


Figure 5.18: Maximum temperatures distribution plots for Malava Agricultural Station for period between 1957-1986 and 1987-2016.

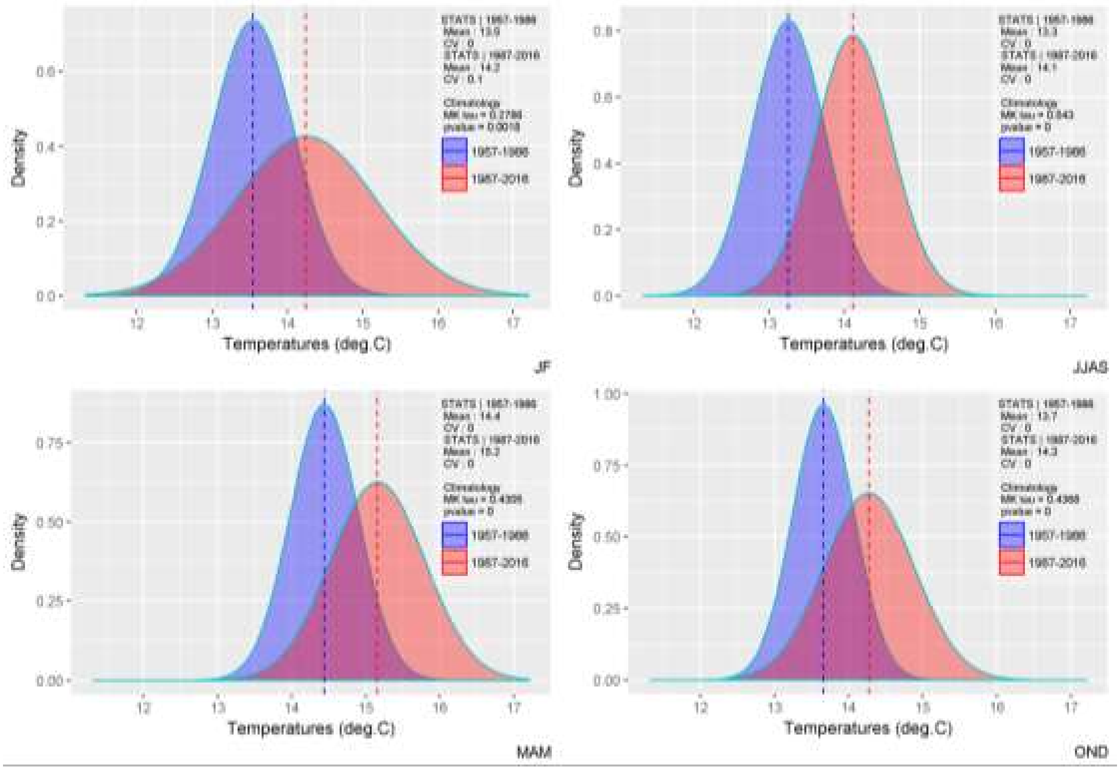


Figure 5.19: Minimum temperatures distribution plots for Malava Agric. Station for period between 1957-1986 and 1987-2016.

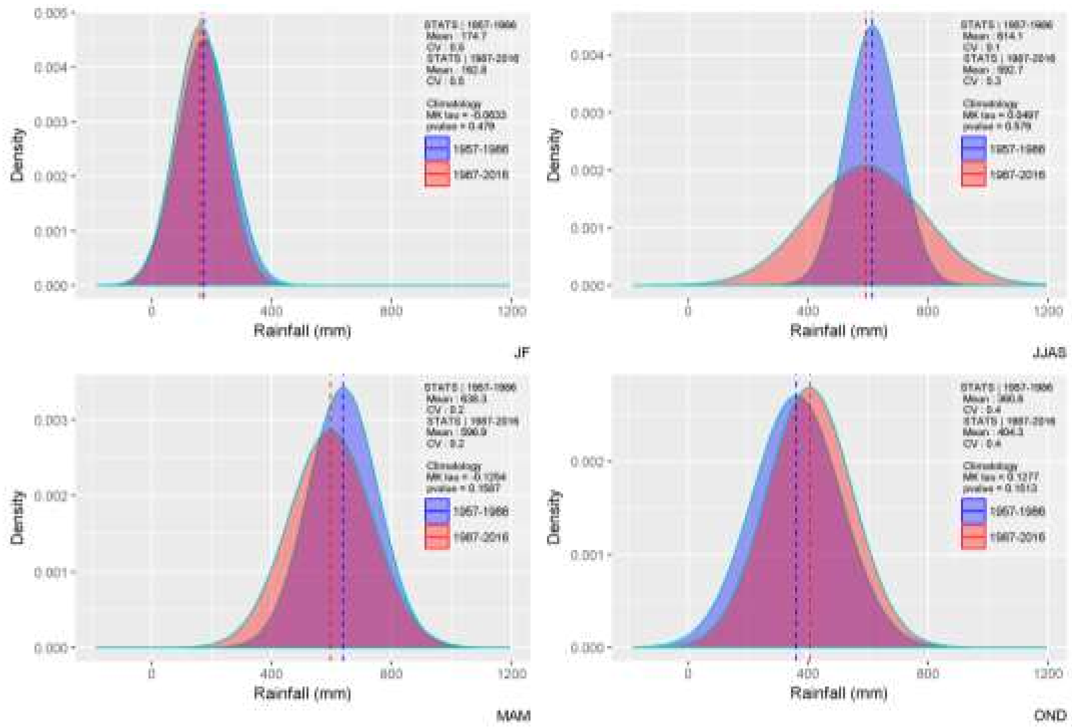


Figure 5.20: Rainfall distribution plots for Malava Agric. Station for period between 1957-1986 and 1987-2016.

At Lugari Forest Station, an increasing of about 0.6ºC - 0.8ºC in minimum temperature (Figure 5.21). An increasing trend of about 0.8ºC - 0.9ºC was also recorded in maximum temperatures the same period (Figure 5.22). A declining trend in mean rainfall was observed in Mar -May (long rains) while Oct-Dec (short rains) recorded an increasing trend (Figure 5.23).

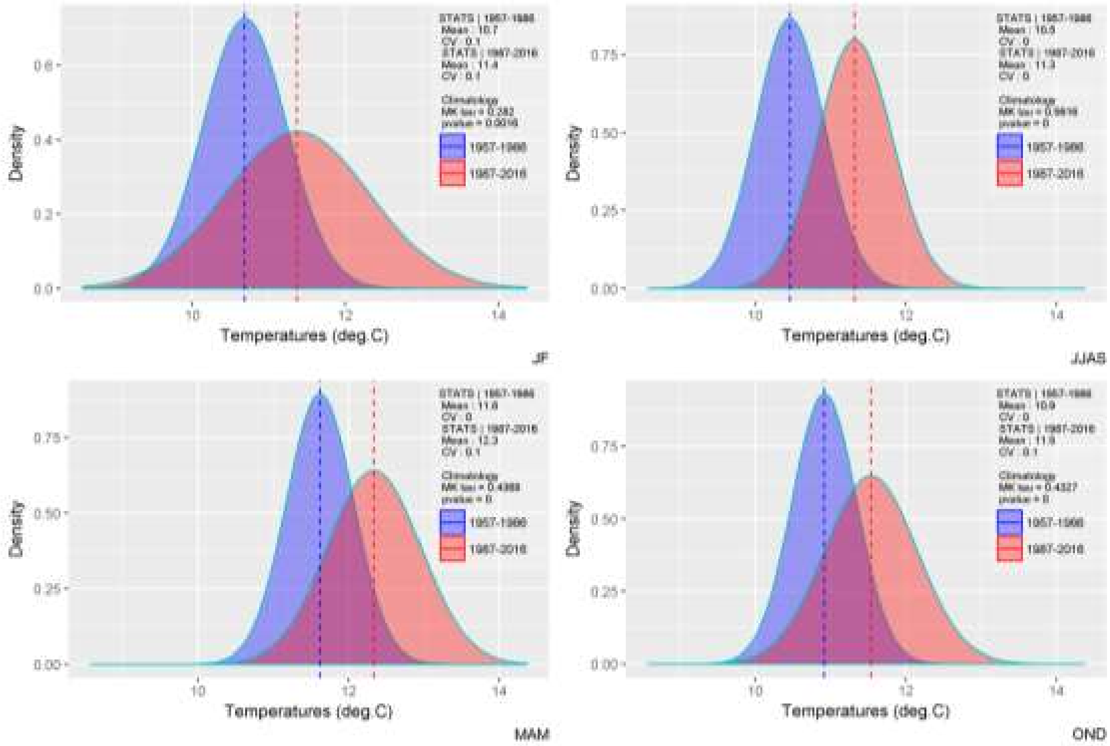


Figure 5.21: Minimum temperatures distribution plots for Lugari Forest Station for period between 1957-1986 and 1987-2016.

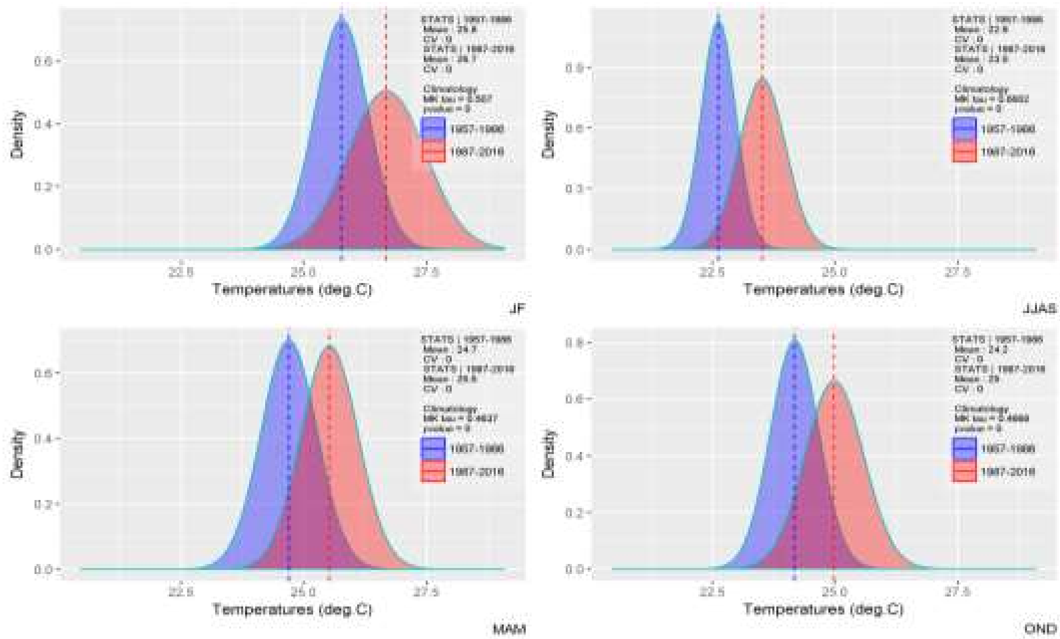


Figure 5.22: Maximum temperatures distribution plots for Lugari Forest Station for period between 1957-1986 and 1987-2016.

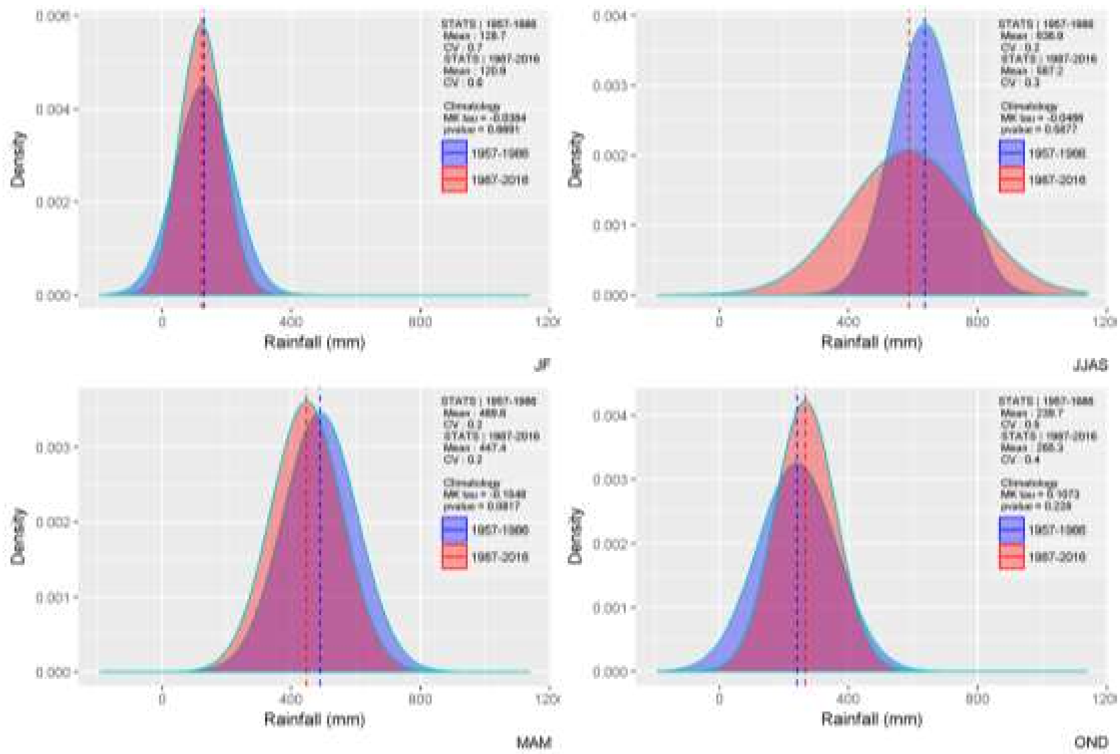


Figure 5.23: Rainfall distribution plots for Lugari Forest Station for period between 1957-1986 and 1987-2016.

Kisii Meteorological station exhibited an upward trend in the mean minimum temperature of about 0.6ºC - 0.8ºC in 1987 to 2016 period (Figure 5.24), similar findings were also observed for maximum temperatures for the same period (Figure 5.25). The Mar -May (long rains) exhibited a declining trend while Oct-Dec (short rains) recorded an increasing trend for the period same (Figure 5.26).

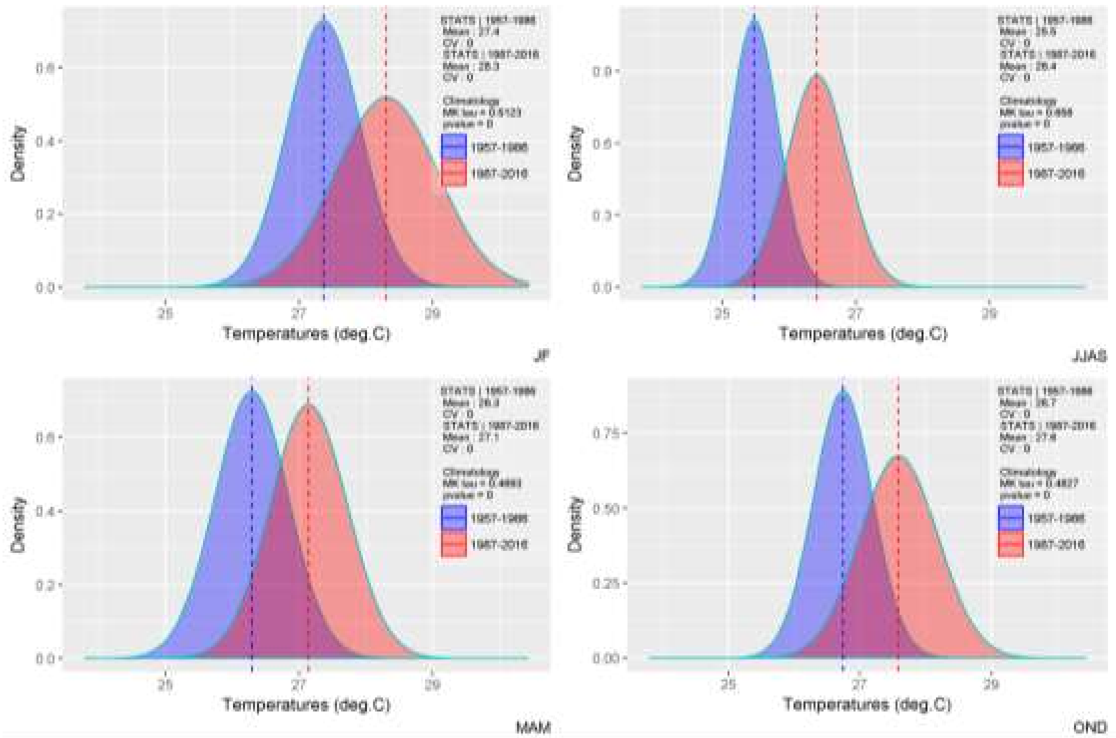


Figure 5.24: Maximum temperatures distribution plots for Kisii Meteorological Station for period between 1957-1986 and 1987-2016.

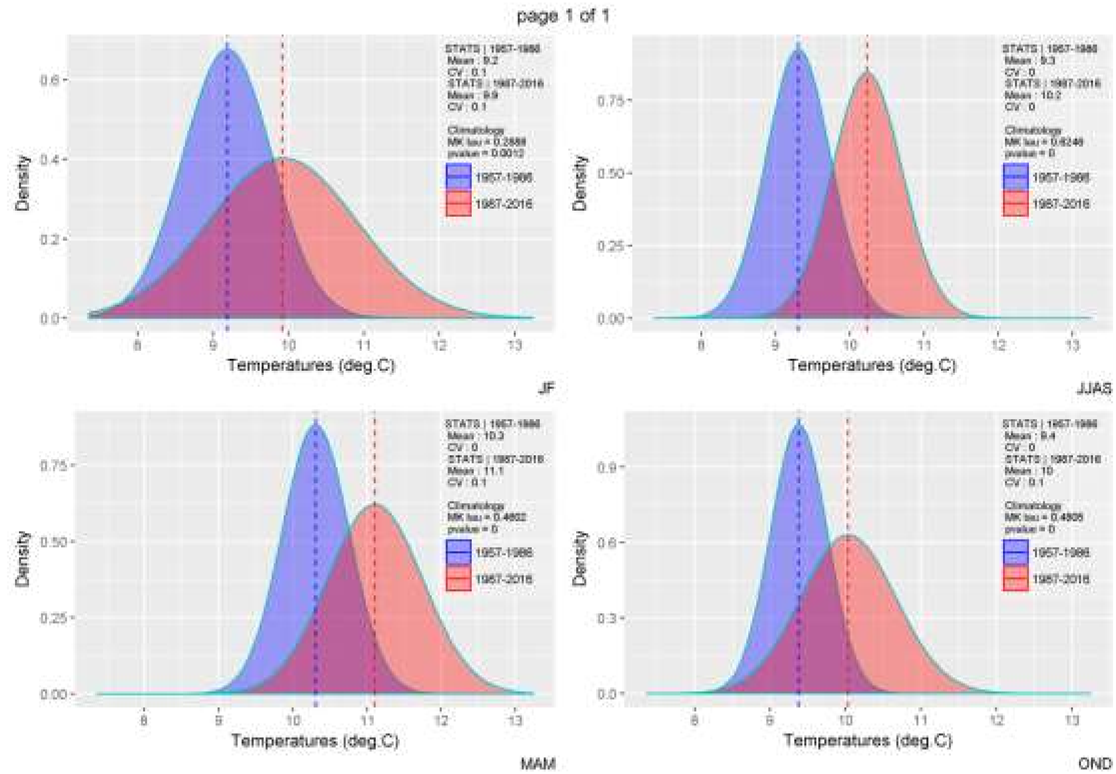

Figure 5.25: Minimum temperatures distribution plots for Kisii Meteorological Station for period between  1957-1986 and 1987-2016.

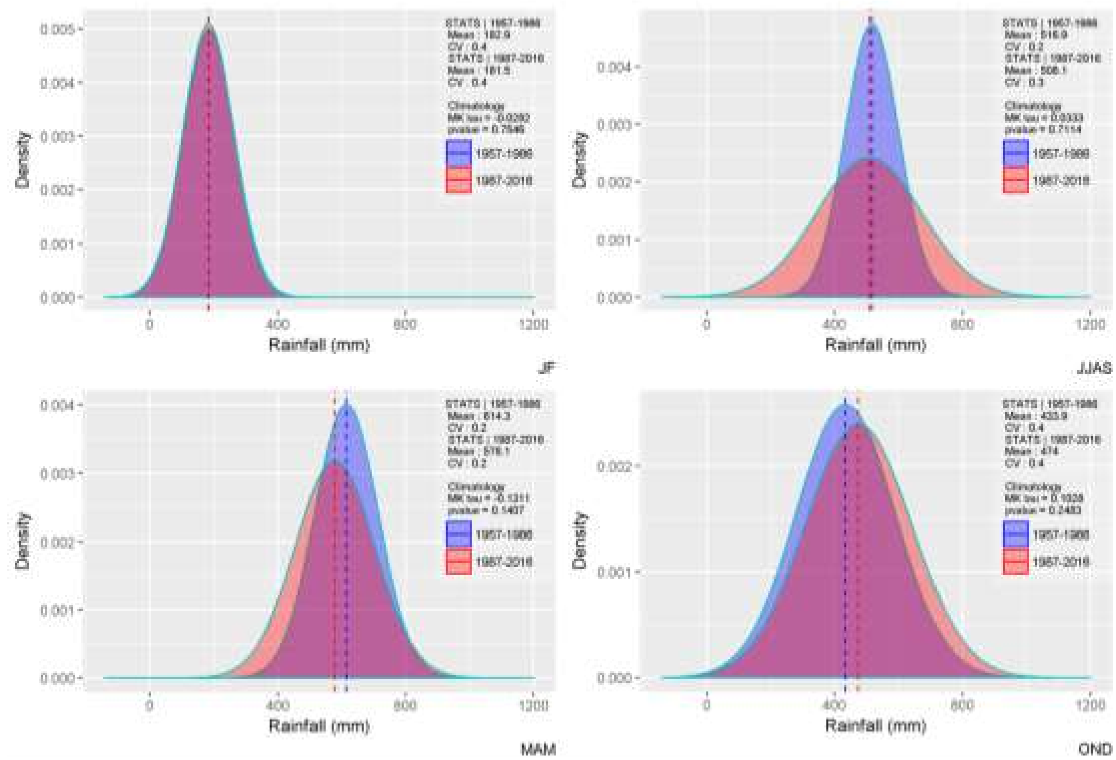

Figure 5.26: Rainfall distribution plots for Kisii Meteorological Station for period between 1957-1986 and 1987-2016.

At Kitale Meteorological Station, the study established an increasing trend in mean of minimum temperature of about 0.6ºC - 0.9ºC for 1987 - 2016 period (Figure 5.27). The mean of maximum temperatures has reliably increased by 1ºC as shown in Figure 5.28. The rainfall trend showed that the mean of Mar -May (long rains) seasonal rainfall had not changed while in increase in OCT-DEC (short rains) was recorded (Figure 5.29).

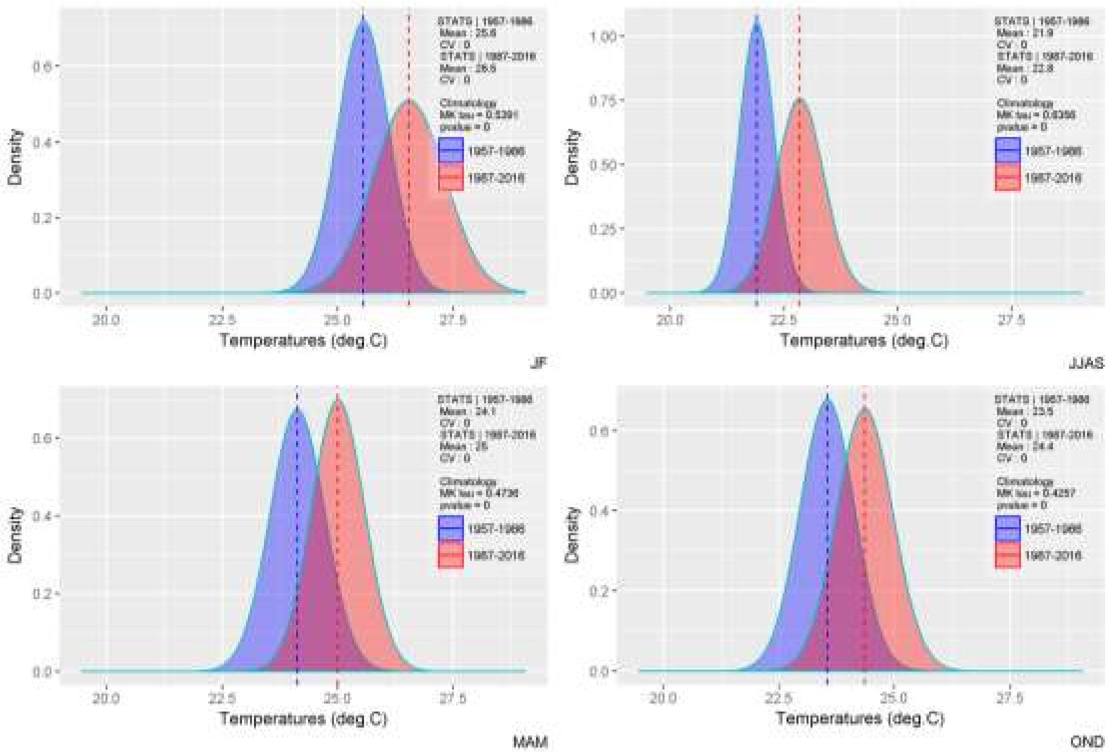


Figure 5.27: Mximum temperatures distribution plots for Kitale Meteorological Station for period between  1957-1986 and 1987-2016.

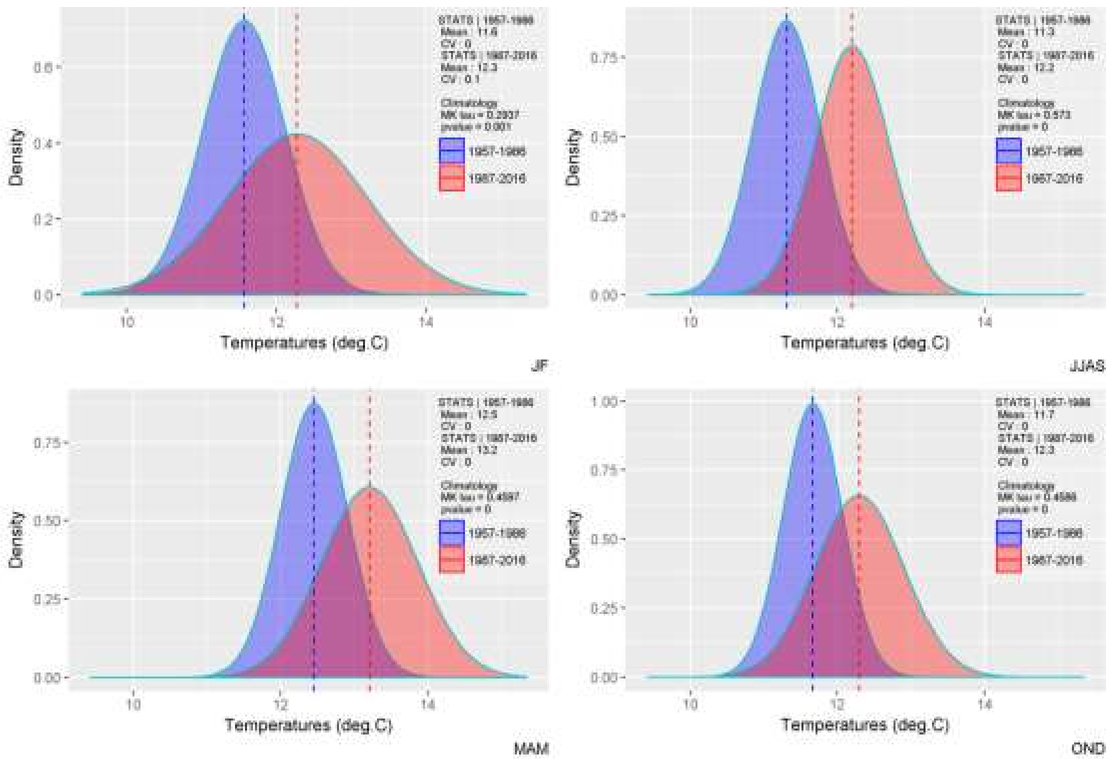


Figure 5.28: Minimum temperatures distribution plots for Kitale Meteorological Station for period between 1957-1986 and 1987-2016.

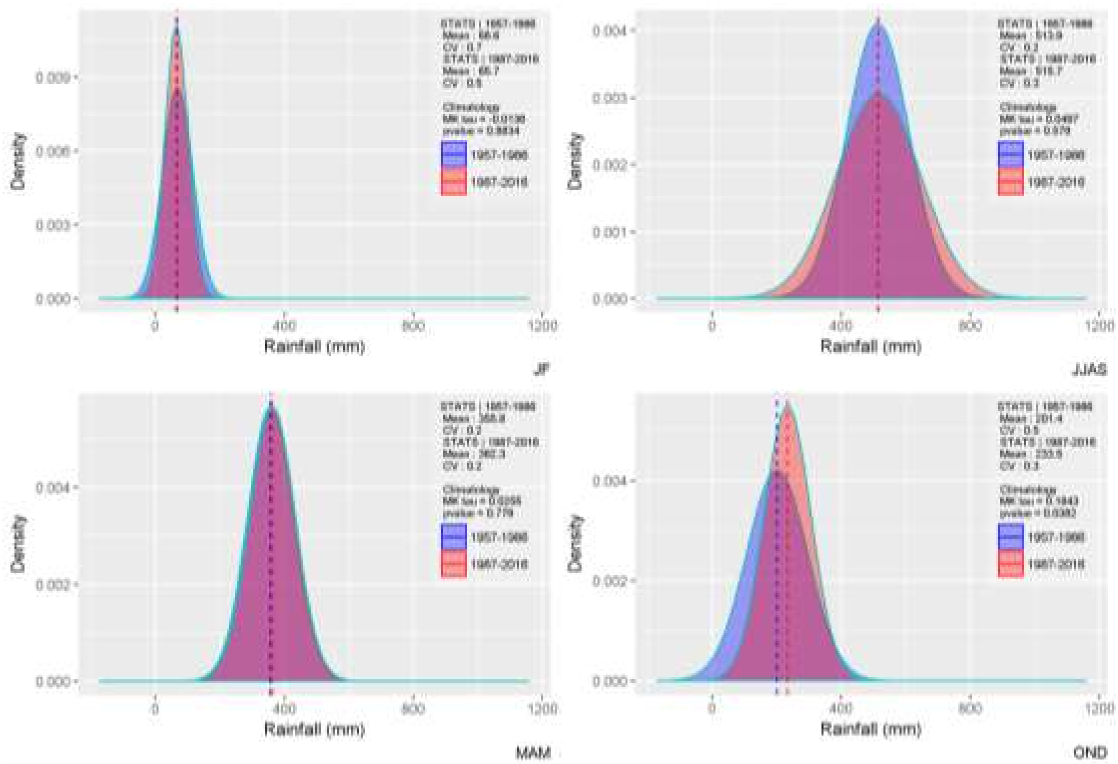


Figure 5.29: Rainfall distribution plots for Kitale Meteorological Station for period between 1957-1986 and 1987-2016.

The Kimilili Forest Station exhibited an upward trend in both the mean of minimum and maximum temperatures of about 0.8ºC - 0.9ºC (Figure 5.30) and 1ºC (Figure 5.31) respectively. A downward trend for Mar-May rains and an upward trend for Oct-Dec was observed for in the period of 1986-2016 (Figure 5.32).

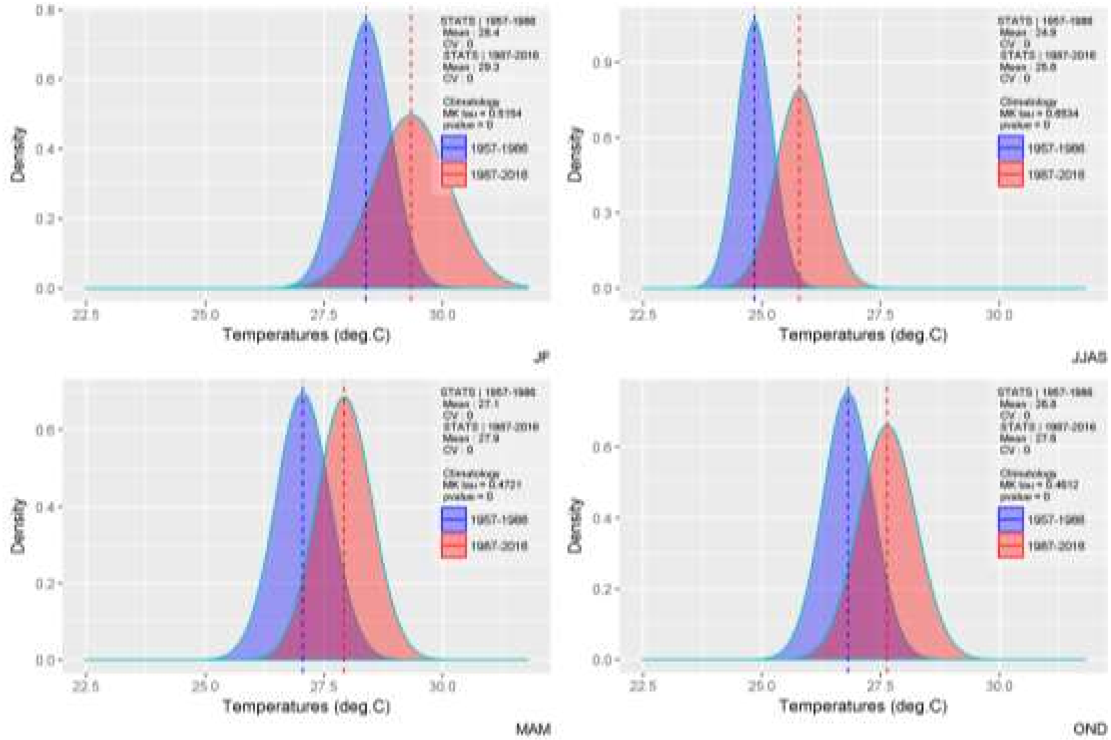


Figure 5.30: Maximum temperatures distribution plots for Kimilili Forest Station for period between 1957-1986 and 1987-2016.

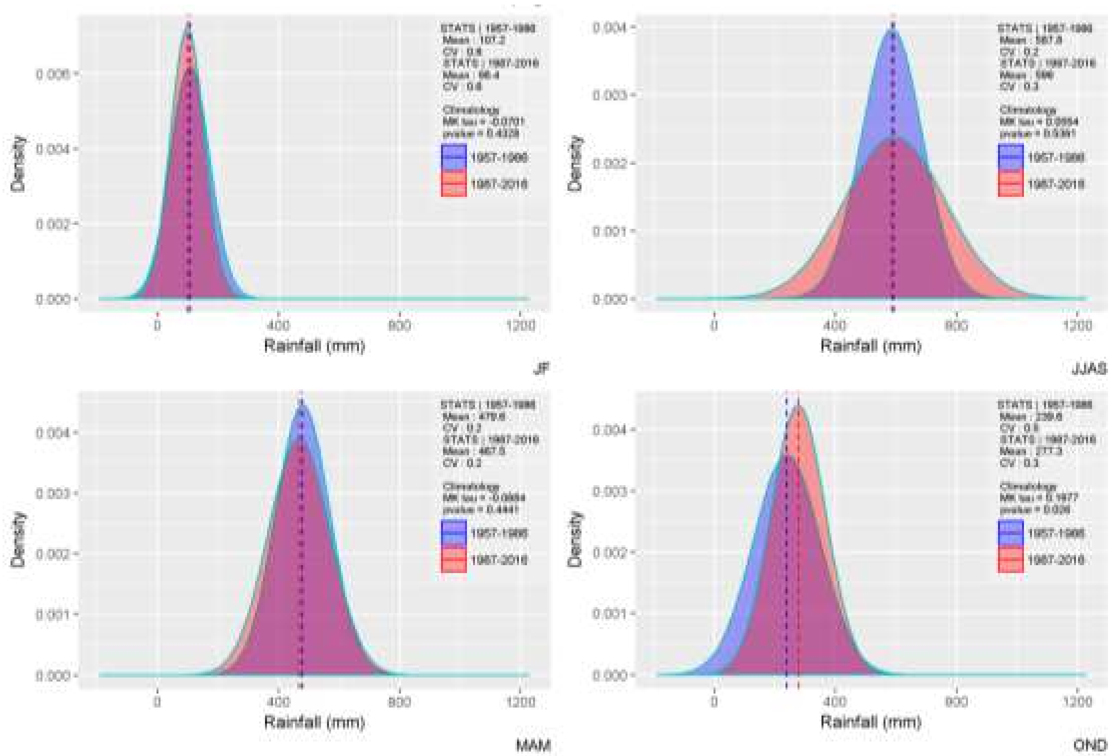


Figure 5.32: Distribution plots of rainfall over Kimilili Forest Station for period between 1957-1986 and 1987-2016.

At Bukembe Station, an upward trend in mean of maximum temperatures of about 0.8ºC - 1ºC was observed (Figure 5.33). Similar trend was also established for the mean of minimum temperatures (0.6ºC - 1ºC) (Figure 5.34). The result if the study further showed a downward trend in Mar -May rains, while Oct-Dec rains an upward trend was observed for the same period (Figure 5.35).

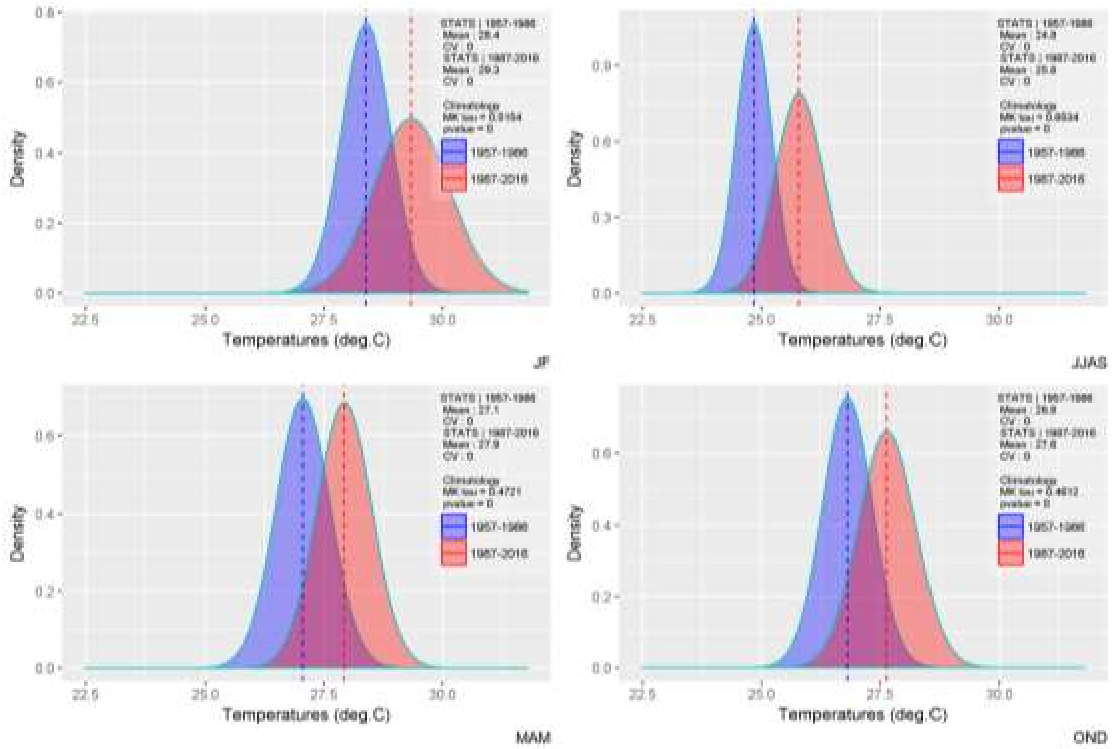


Figure 5.33: Maximum temperatures distribution plots for Bukembe for period between 1957-1986 and 1987-2016.

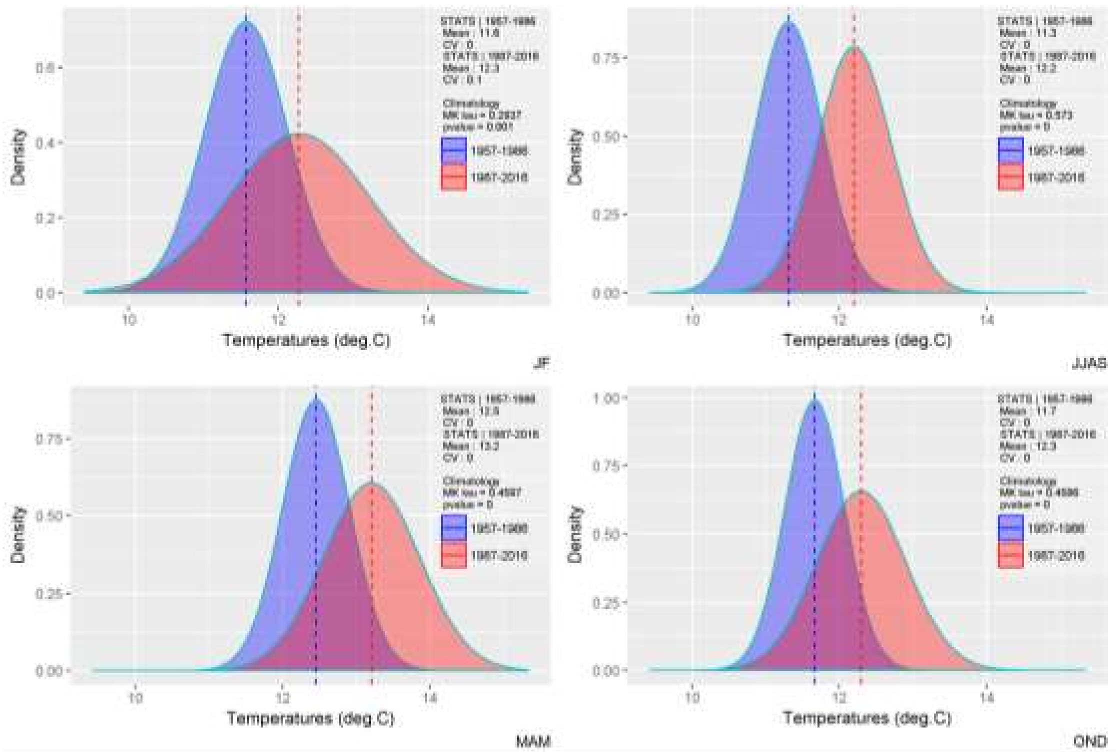


Figure 5.34: Minimum temperatures distribution plots for Bukembe for period between 1957-1986 and 1987-2016.

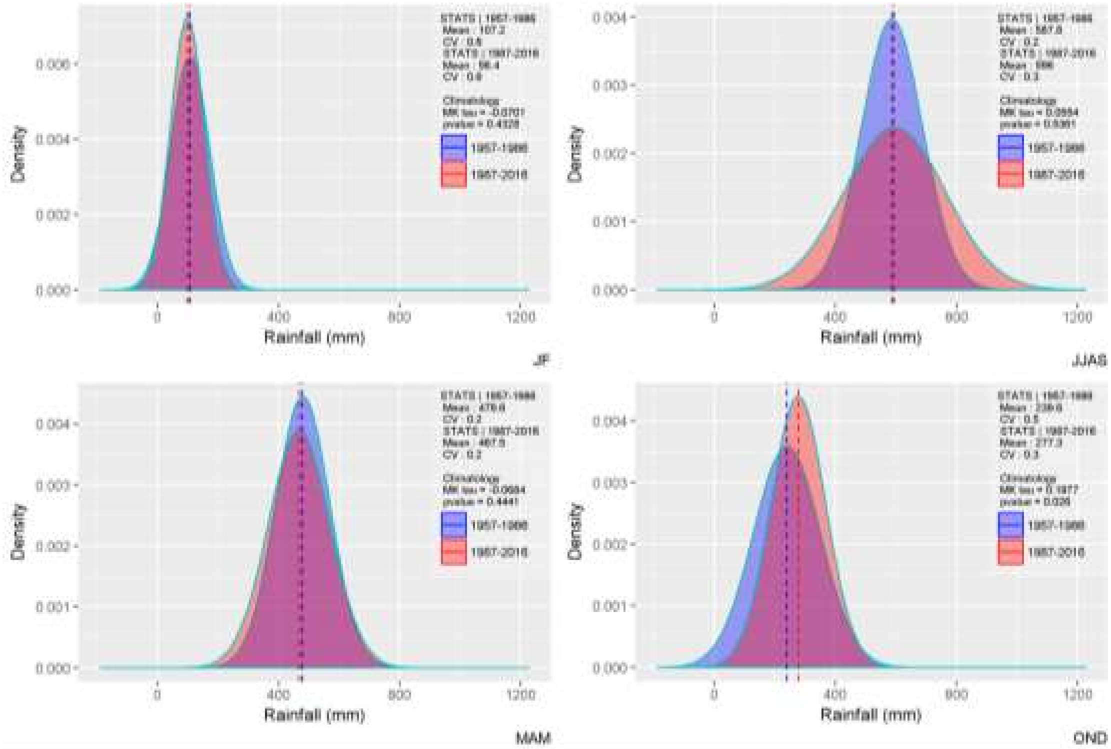


Figure 5.35: Rainfall distribution plots for Bukembe for period between 1957-1986 and 1987-2016.

At Kakamega Meteorological Station, an increasing trend in the mean for minimum temperature of about (0.6ºC - 0.8ºC) was exhibited (Figure 5.36). The maximum temperature exhibited an increase of between 0.8ºC and 1ºC in the period 1987 to 2016 (Figure 5.37). A declining trend was observed for Mar -May (Long rains) seasonal rainfall, while Oct-Dec recorded an increasing trend in the same period of 1986-2016 (Figure 5.38).

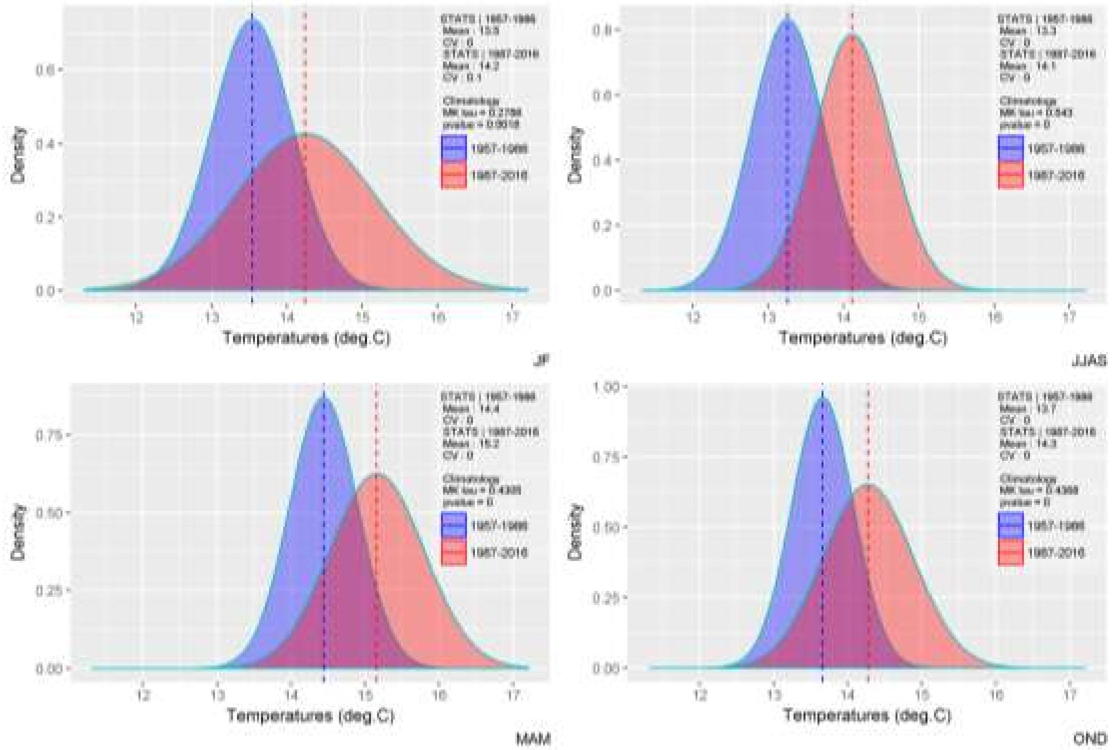


Figure 5.36: Minimum temperatures distribution plots for Kakamega Meteorological Station for period between 1957-1986 and 1987-2016.

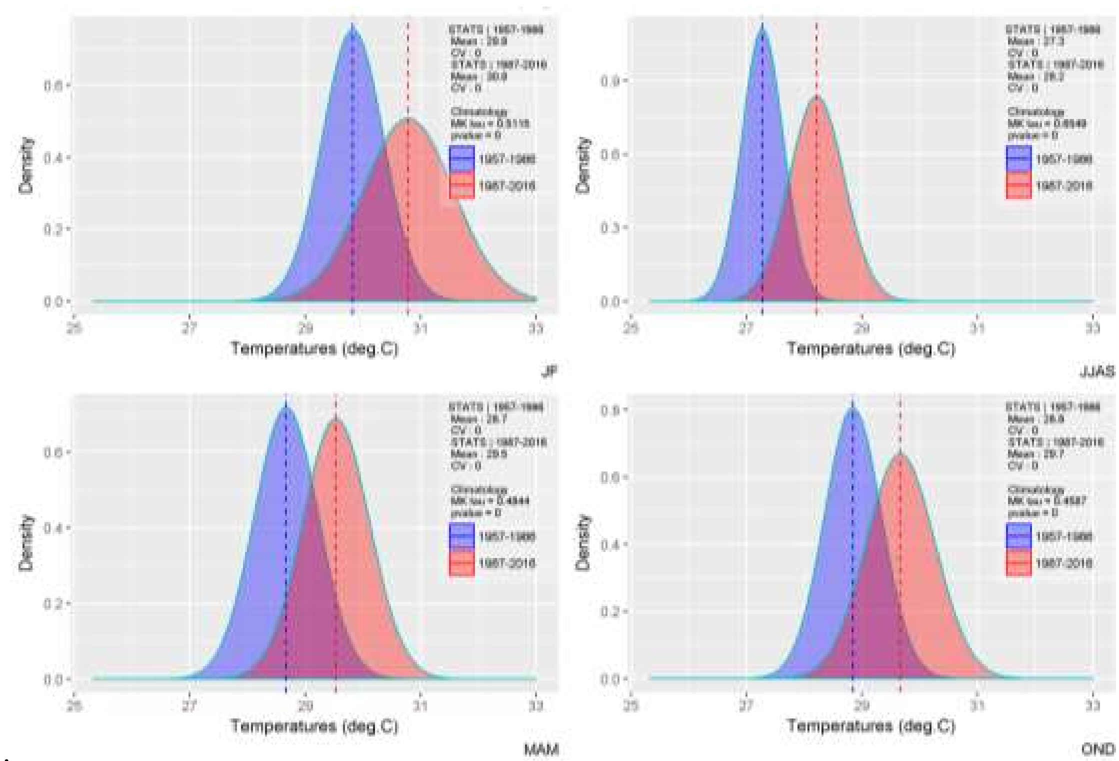


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Figure 5.37: Maximum temperatures distribution plots for Kakamega Meteorological Station for period between 1957-1986 and 1987-2016.

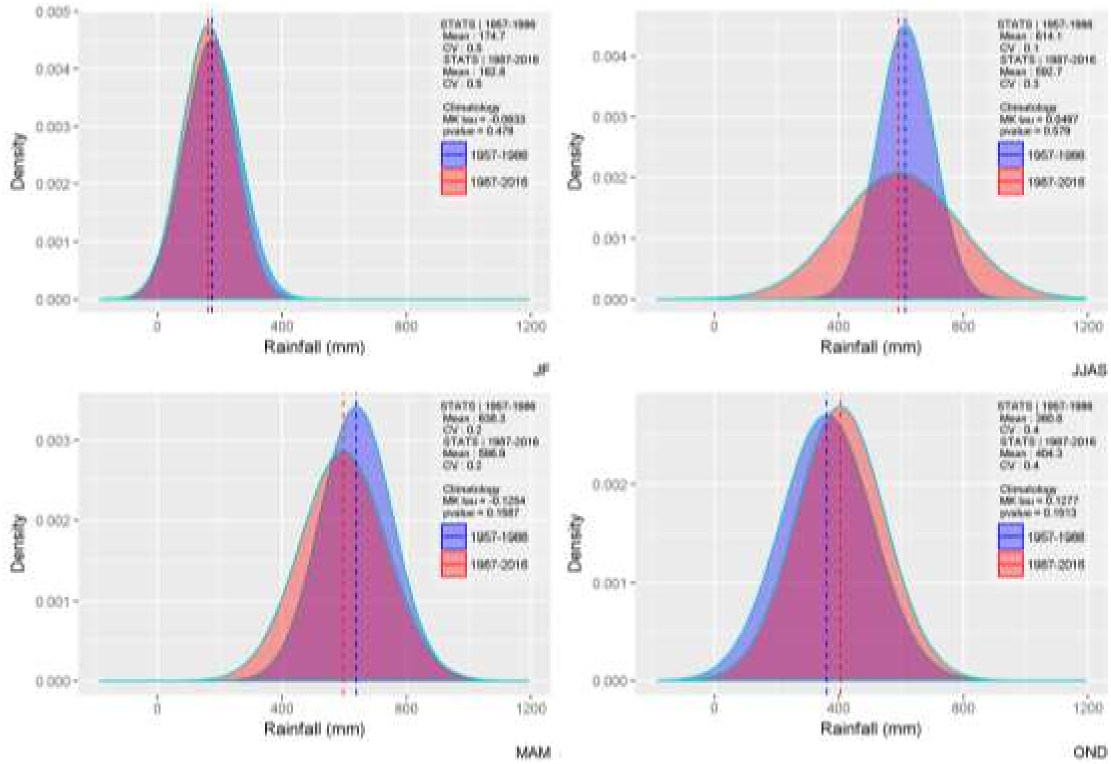


Figure 5.38: Rainfall distribution plots for Kakamega Meteorological Station for period between 1957-1986 and 1987-2016.

At Port-Victoria Mission, the study established an increasing trend in the mean of minimum temperatures (0.6ºC - 0.8ºC) for 1987 - 2016 period (Figure 5.39). The study finding in Figure 5.40 exposed a higher positive trend in the mean of maximum temperatures of about 0.9ºC - 1.1ºC for 1987 - 2016 period (Figure 5.40). An upward trend in both Mar -May rains and Oct-Dec rains was observed in 1987-2016 period (Figure 5.14).

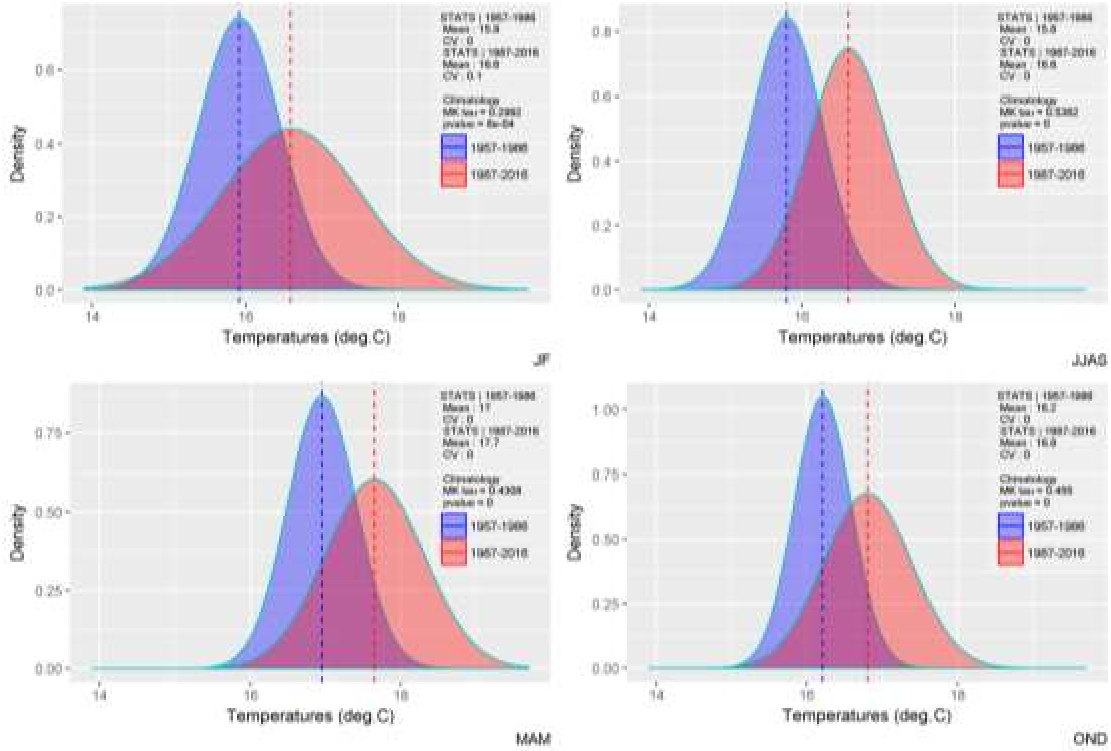



Figure 5.39: Minimum temperatures distribution plots for Port Victoria Mission Station for period between 1957-1986 and 1987-2016.

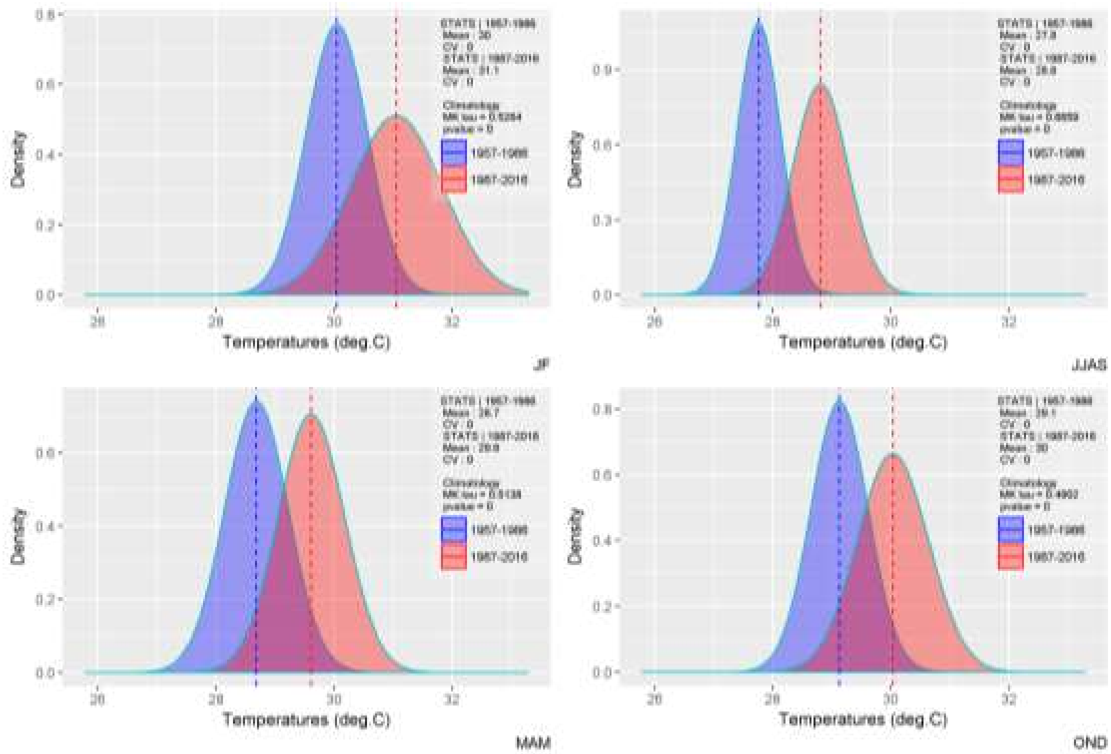



Figure 5.40: Maximum temperatures distribution plots for Port Victoria Mission Station for period between 1957-1986 and 1987-2016.

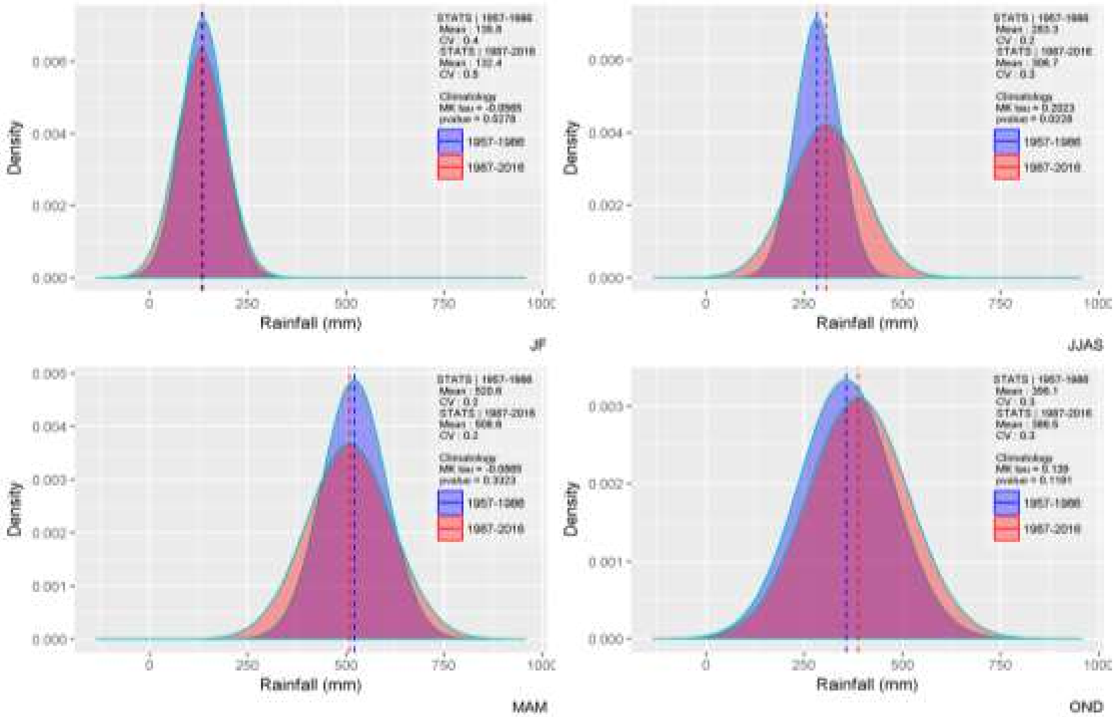



Figure 5.41: Rainfall distribution plots for Port Victoria Mission Station for period between 1957-1986 and 1987-2016.

Kisumu Meteorological Station exhibited an increasing trend of about 0.6ºC - 0.8ºC in the mean of minimum temperature (Figure 5.42). The maximum temperatures also revealed an upward trend of (1ºC - 1.1ºC) for the same period (Figure 5.43). A downward trend was observed in Mar -May rains and a slight upward trend for Oct-Dec rains (Figure 5.44).

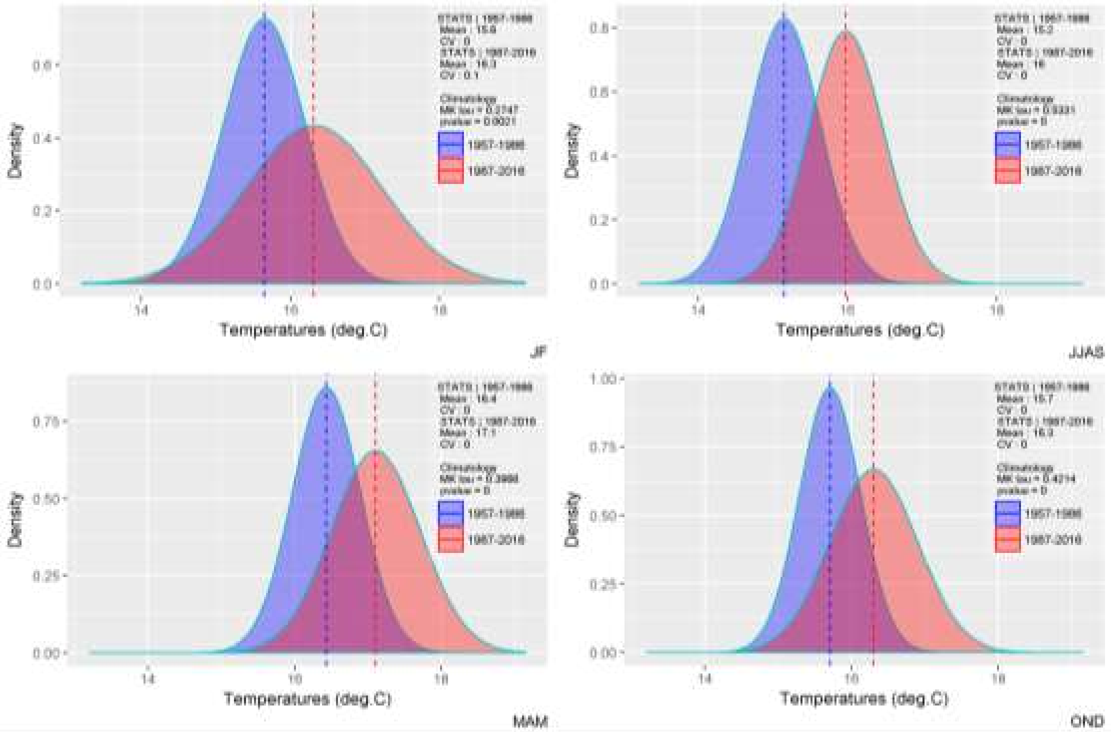



Figure 5.42: Minimum temperatures distribution plots for Kisumu Meteorological Station for period between 1957-1986 and 1987-2016.

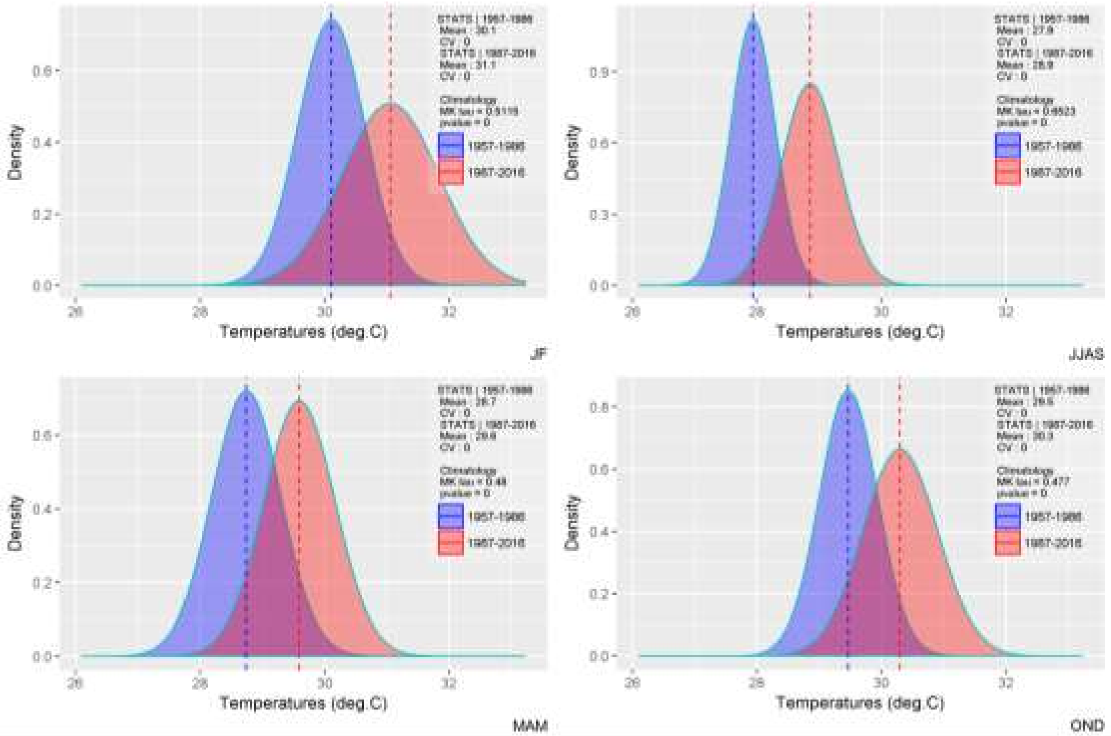



Figure 5.43: Maximum temperatures distribution plots for Kisumu Meteorological Station for period between 1957-1986 and 1987-2016.

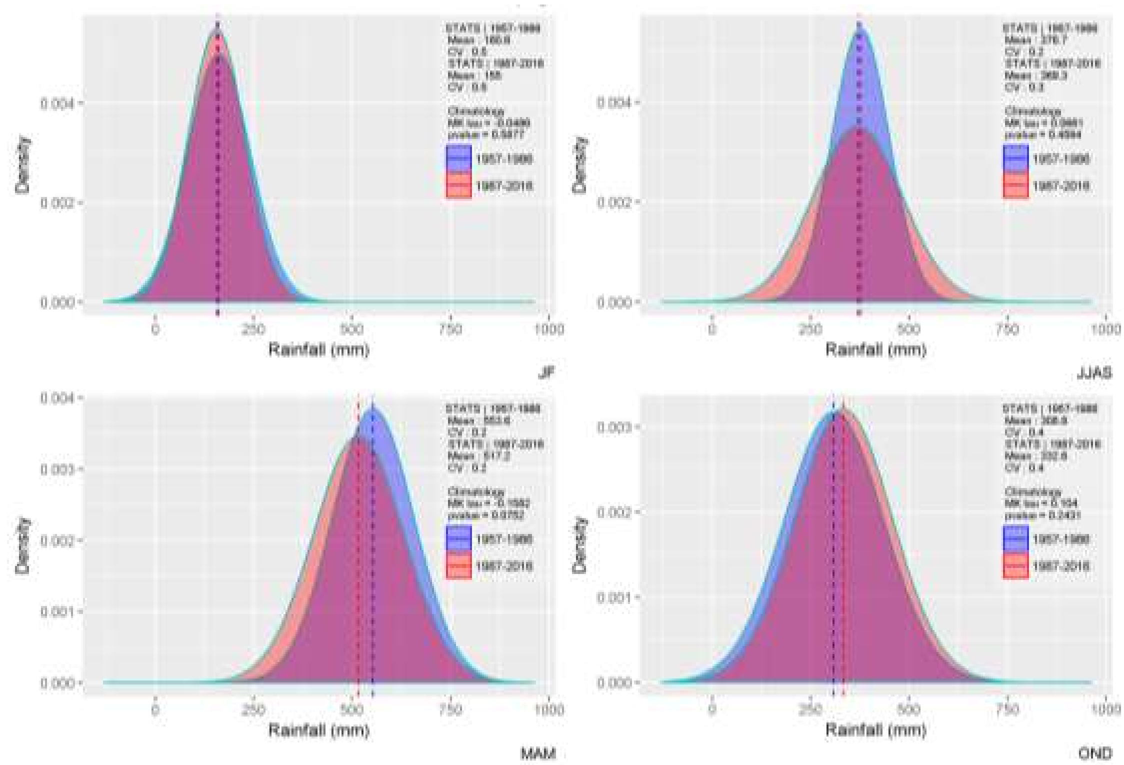



Figure 5.44: rainfall distribution plots for Kisumu Meteorological Station for period between 1957-1986 and 1987-2016.

Kaptagat Forest Station exhibited an upwards trend in the mean minimum temperature of about 0.5ºC - 0.8ºC in 1987 to 2016 period (Figure 5.45), similar findings were also observed for maximum temperatures for the same period (Figure 5.46). The results of the study further showed that Mar -May rains had significantly decline while Oct-Dec rains recorded a significantly low increase for the period same (Figure 5.47).

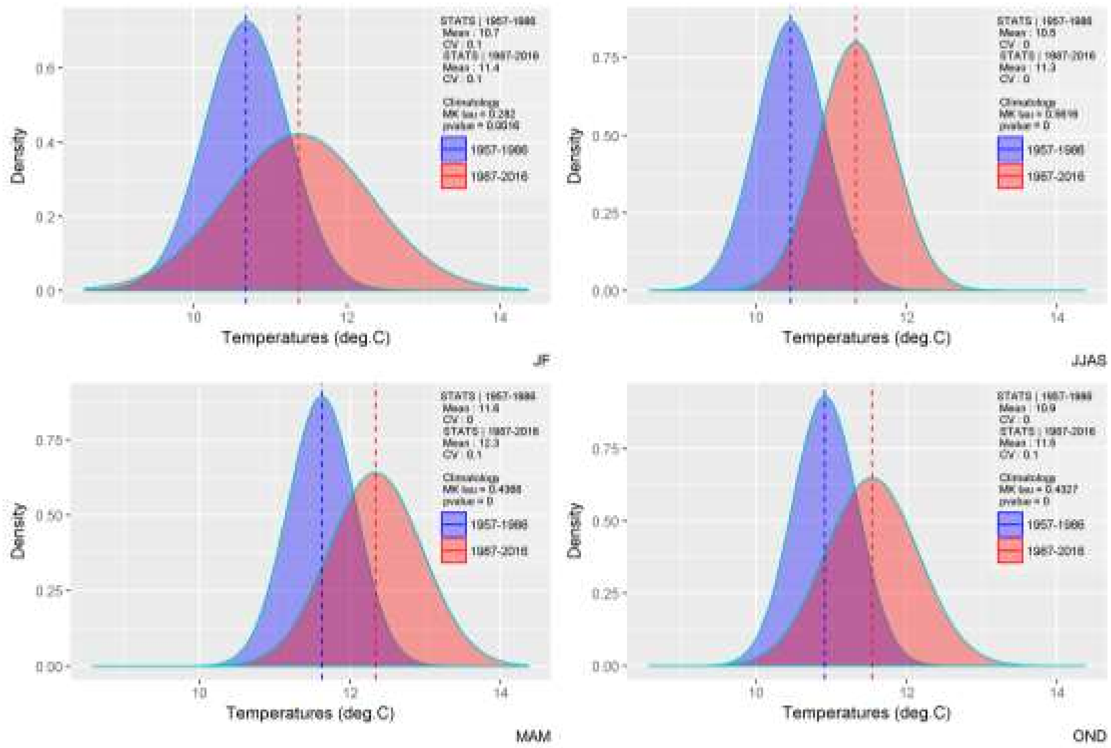



Figure 5.45: Minimum temperatures distribution plots for Kaptagat Forest Station for period between 1957-1986 and 1987-2016.

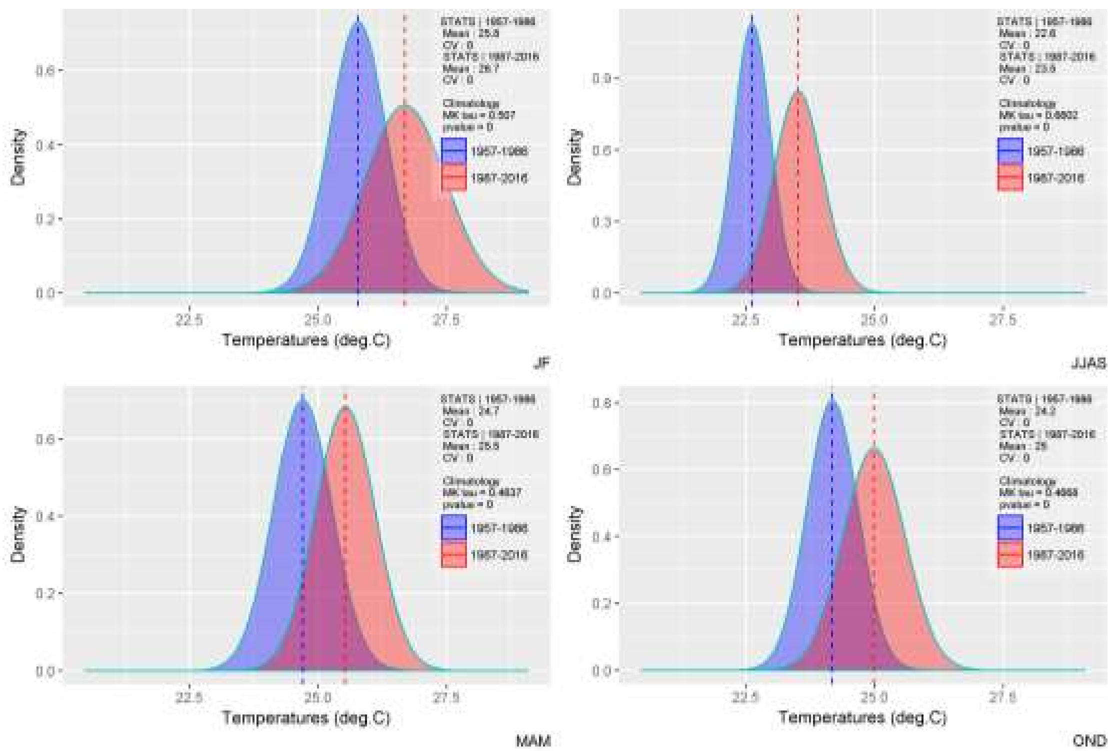



Figure. 5.46: Maximum temperatures distribution plots for Kaptagat Forest Station for period between 1957-1986 and 1987-2016.

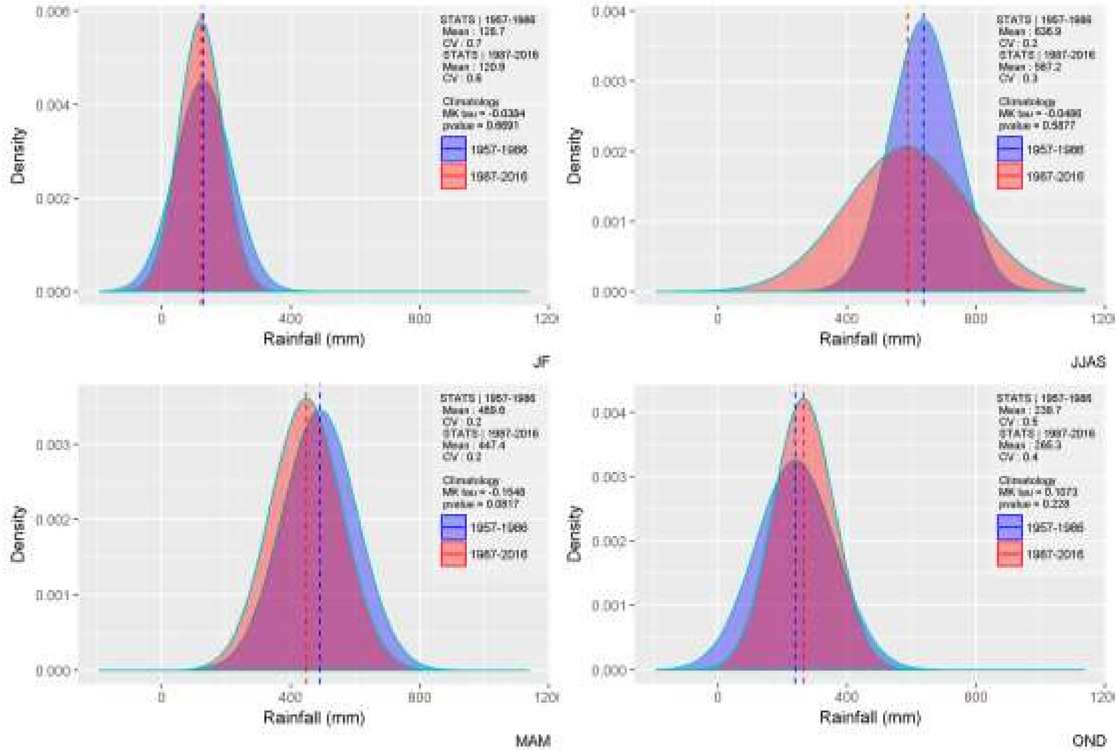



Figure 5.47: Rainfall distribution plots for Kaptagat Forest Station for period between 1957-1986 and 1987-2016.

### 5.2.3.1 Determination of Rainfall Onsets and Cessation over Basin

The study finding showed the climatological wet days observed from the black smoothed curve in figure 5.48 with onsets typically around the first blue triangle and cessation at around the red triangle. The second onset was around the second blue triangle. The current year was shown by the green line, which was an accumulation of daily rainfall anomaly (subtracted from the climatological daily rainfall) where onsets were seen as days on which the rainfall started persisting towards a positive anomaly; the reverse indicated a cessation. The blue line showed the observed daily rainfall. Since the region was found to have a bimodal rainfall regime. The present study extended the methodology by adopting the one used by Dunning et al. (2016) by considering two onsets and two cessations in a year.

The current study established that onsets of long rains in the whole region were centered around fifty to hundred Julian days, which is interpreted as dates between mid-February

(February 19$^{th}$) to the beginning of April (April 10$^{th}$), while the Mar -May cessations were centered around 100 to 200 Julian days, translating to early April in some regions to mid-July (July 19$^{th}$) in others, as indicated in Figure 4.48.

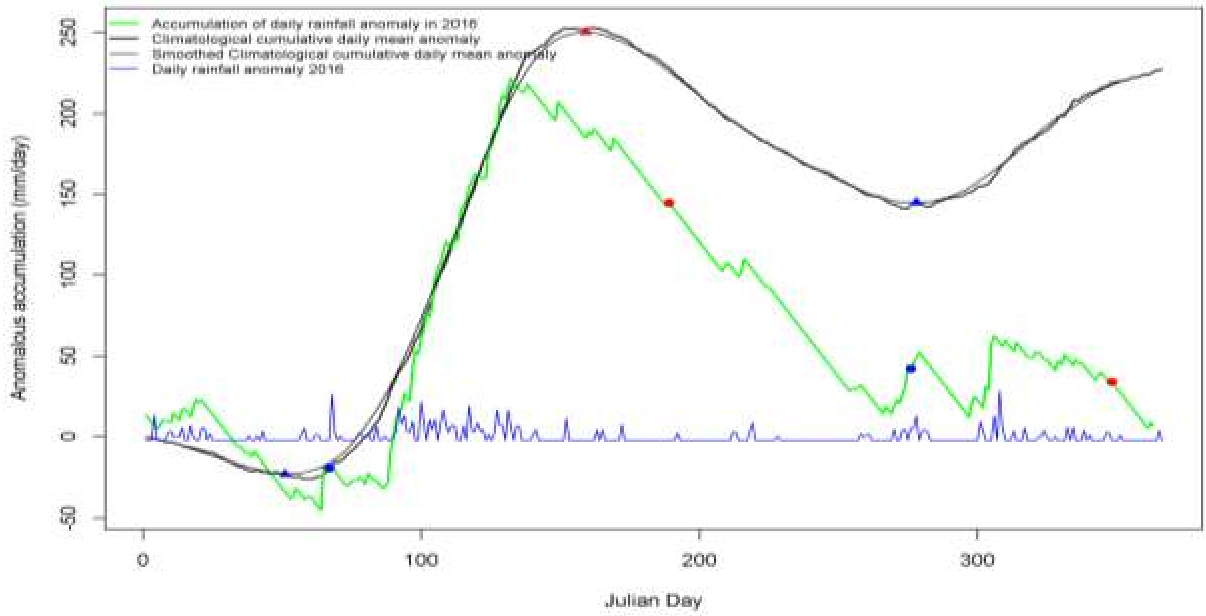



Figure 5.48: Time series plot for the Hydrologic year; climatological daily mean rainfall anomaly (black curve), and cumulative daily mean rainfall anomaly (green) for Bukembe station averaged over 1981–2016.

### 5.2.3.2 Variability in Rainfall Onsets and Cessation Days

The analysis of variability in onset and cessation days was anchored on the number of rainy days. This is given as the duration between onsets and cessations and together with onset days and cessations dates were analyzed to check for variability.

The study established that the most varied aspects of the hydrologic year were rainfall cessations for the Mar-Apr rains and the onset of the Oct-Dec rains at each station separately (Figure 5.49) where very long box plots were exhibited. The observed variabilities in both cessations of Mar-Apr rains and the onset for Oct-Dec rains have a potential effect on the number of rainy days. The findings revealed at almost 50% variability in the Mar-May rainfall onsets, which was interpreted to fall between mid-February and early April (in the range of 50 and 100 Julian days) at the following meteorological station; Kericho, Kisumu and Sabatia Forest Station, while at least 30% variability was observed in Oct-Dec rainfall cessations (in the range of 100 to 200 Julian days) for all other weather station's part from Muhuru Bay Hydromet station.

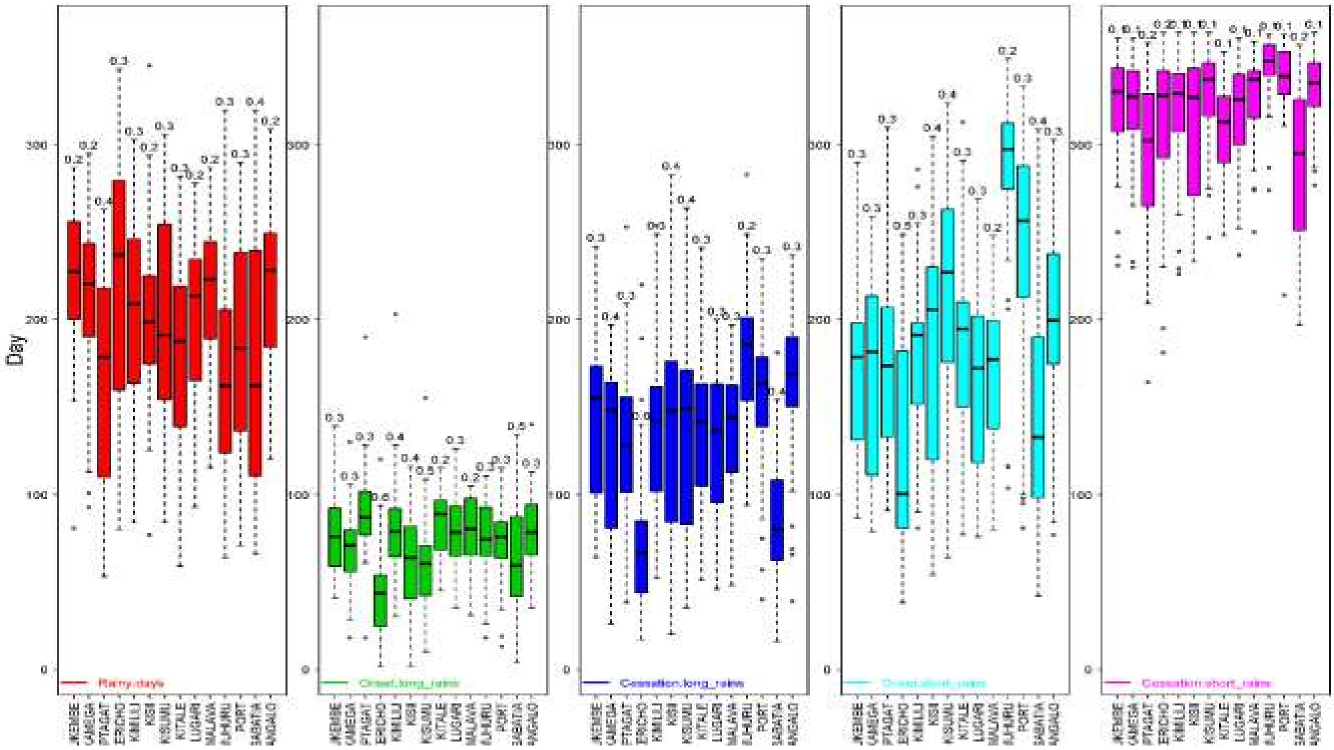


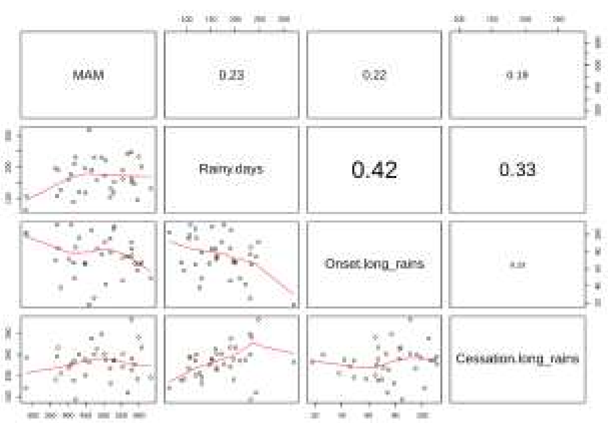

Figure 5.49: Boxplots displaying Variability in a number of rainy days, Rainfall Onsets and Cessation Days for both Mar-May and Oct-Dec rains. Inserted are the coefficients of variability

### 5.2.4 Relationships Between Variations in Rainfall Amount and Onsets and Cessations

The study finding showed no association between seasonal rainfall and the number of rainy days in ten out of fourteen selected weather stations. These weather stations included; Muhuru Hydromet station (Figure 5.50), Sabatia (Figure 5.51), Kericho (Figure 5.52), Malava (Figure 5.53), Lugari (Figure 5.54), Kaptagat (Figure 5.55), Kisii (Figure 5.56), Kitale (Figure 5.57), Port- Victoria (Figure 5.60) and Kisumu (Figure 5.61). Some correlation between Mar -May and Oct-Dec seasonal rainfall was, however, observed at Bukembe (Figure 5.58) and Kakamega Meteorological Station (Figure 5.59) respectively.

The findings further showed a significant number of the weather stations exhibited a weak correlation between the rainy days and the onsets for both the Oct-Dec and Mar -May rains within the same year. The results of the study for Muhuru Hydromet Station (Figure 5.50), Sabatia Forest Station (Figure 5.51), Malava Forest Station (Figure 5.53), Kisumu Meteorological Station (Figure 5.61), Sangalo Institute Station (Figure 5.62) and Kimilili meteorological station (Figure 5.63) on the other hand, exhibited a correlation between rainy days and onsets in both Mar -May and Oct-Dec rains. Similar observations ware observed at Kericho Meteorological Station (Figure 5.52) and Port- Victoria Mission Station (Figure 5.60), only for Oct-Dec rains.

The study further established a strong correlation between MAR -MAY rainfall onsets and cessation with exception of Muhuru Bay Hydromet Station (Figure 5.53), Malava Forest Station (Figure 5.53), Kisumu Meteorological Station (Figure 5.61), Bukembe (Figure 5.58) and Sangalo Institute Station (Figure 5.62). Moreover, a weak correlation between Oct-Dec rainfall onsets and cessations was observed for majority of the stations, except Kisii Meteorological station which exhibited a strong correlation in both the Mar -May and Oct-Dec rains.



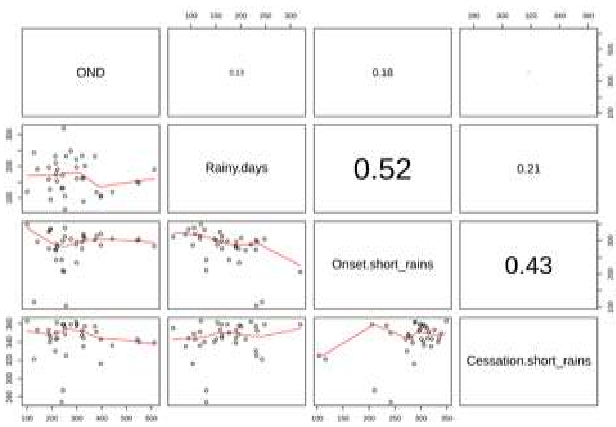



Figure 5.50: Paired scatterplots showing correlations between main rainy seasons (Mar -May & Oct-Dec) and other wet seasonal parameters over Muhuru Bay Hydromet Station.

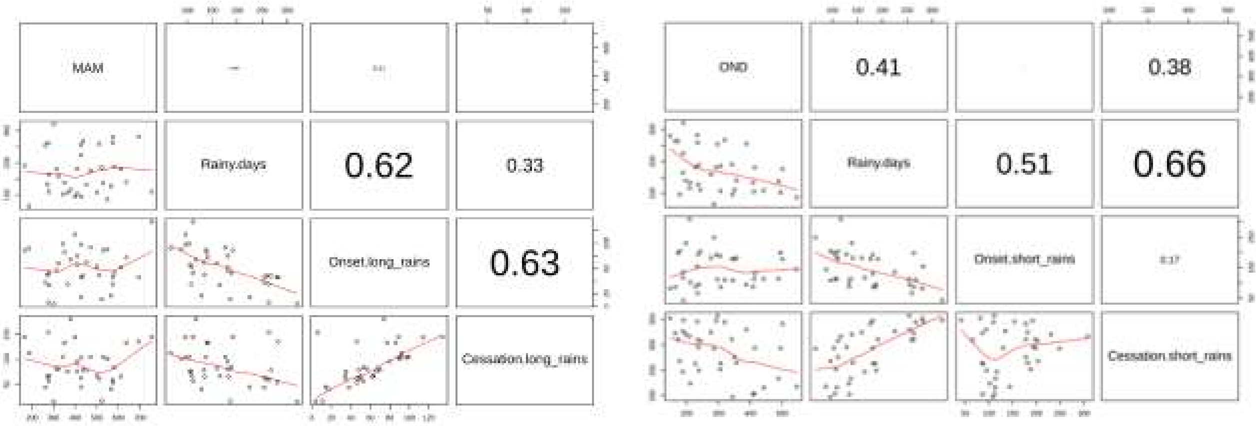



Figure 5.51: Figure 5.50: Paired scatterplots showing correlations between main rainy seasons (Mar -May & Oct-Dec) and other wet seasonal parameters over Sabatia Forest Station.

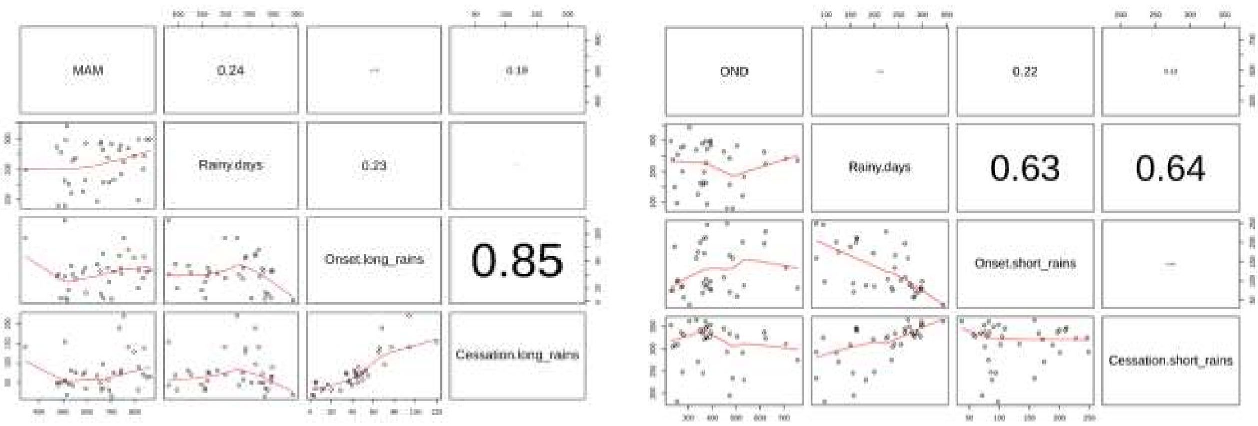



Figure 5.52: Paired scatterplots showing correlations between main rainy seasons (Mar -May & Oct-Dec) and other wet seasonal parameters over Kericho Meteorological Station.

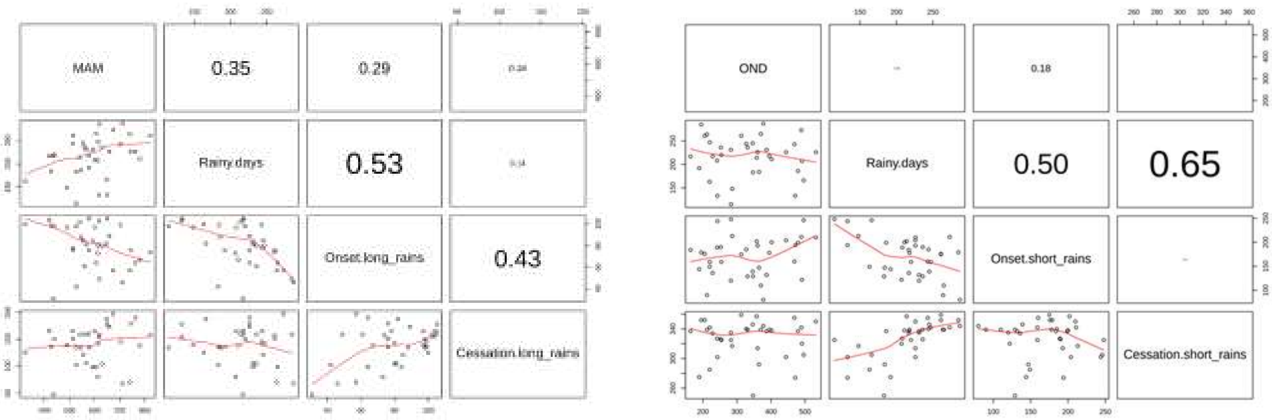



Figure 5.53: Paired scatterplots showing correlations between main rainy seasons (Mar -May & Oct-Dec) and other wet seasonal parameters over Malava Forest Station.

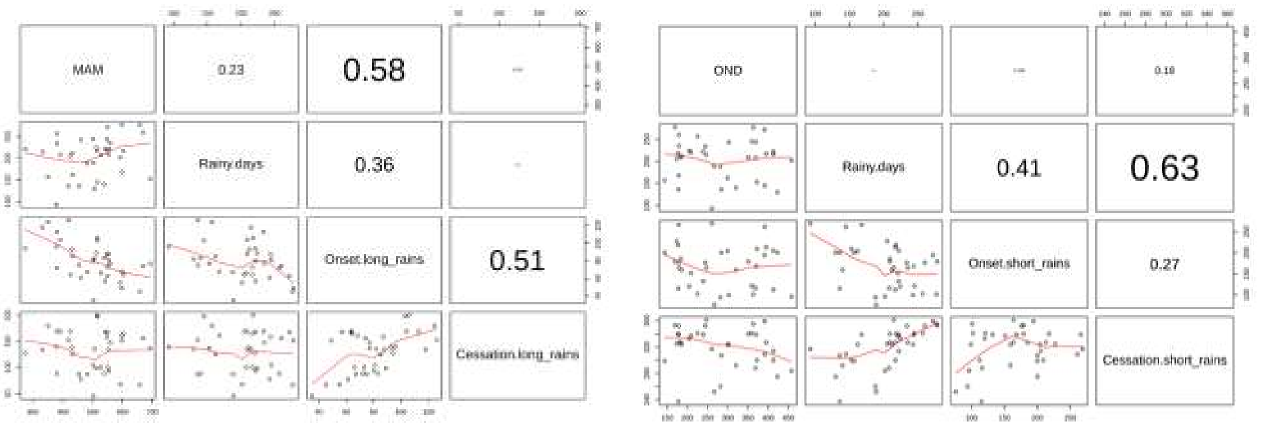



Figure 5.54: Paired scatterplots showing correlations between main rainy seasons (MAR - MAY & OCT-DEC) and other wet seasonal parameters over Lugari

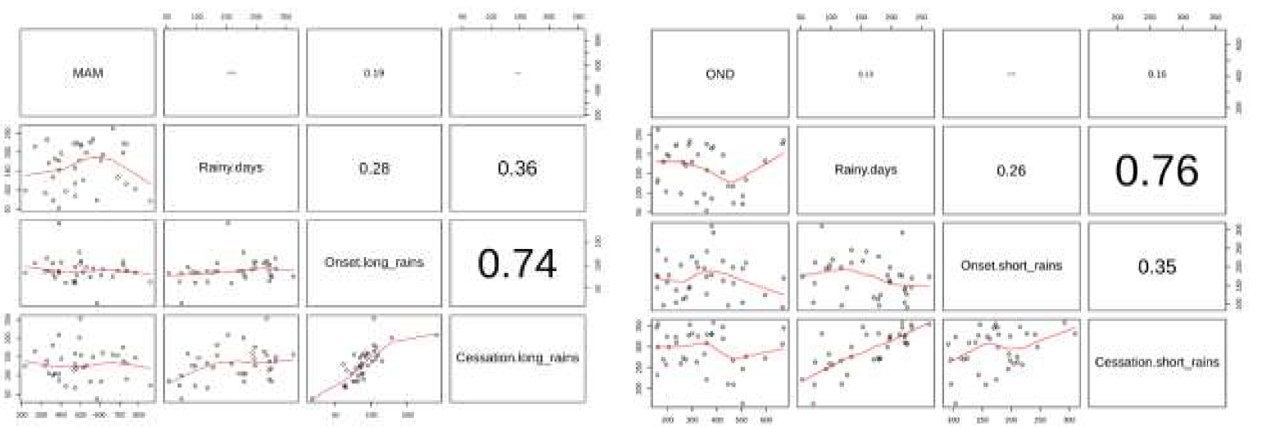



Figure 5.55: Paired scatterplots showing correlations between main rainy seasons (Mar -May & Oct-Dec) and other wet seasonal parameters over Kaptagat.

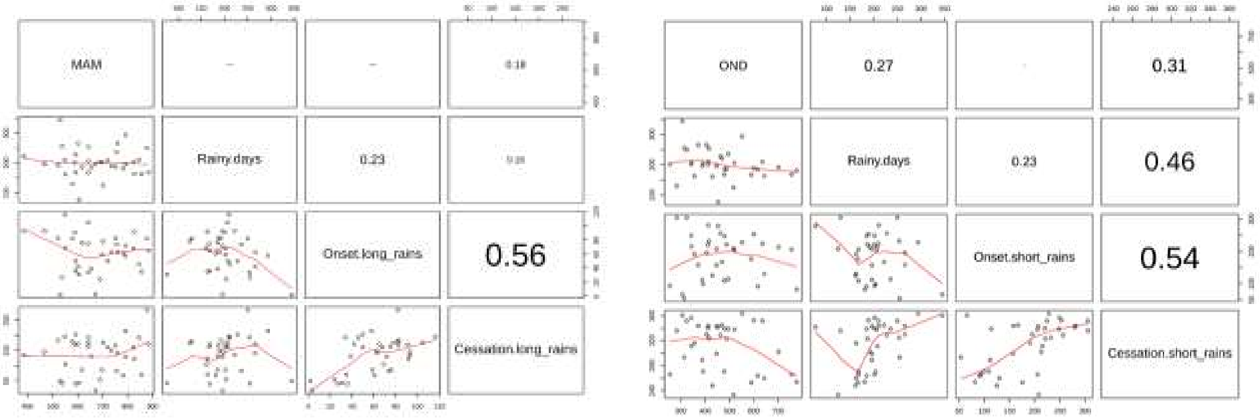



Figure 5.56: Paired scatterplots showing correlations between main rainy seasons (Mar -May & Oct-Dec) and other wet seasonal parameters over Kisii Meteorological Station.

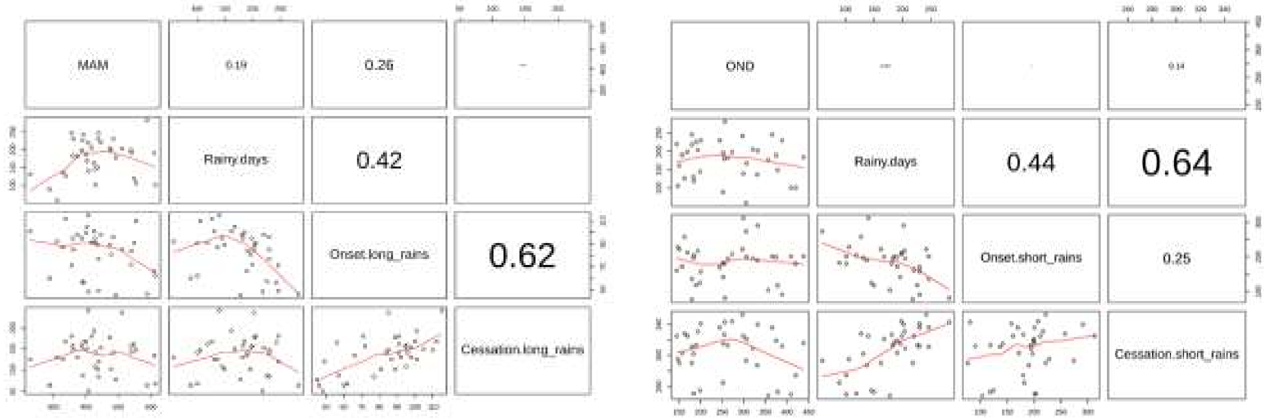



Figure 5.57: Paired scatterplots showing correlations between main rainy seasons (Mar -May & Oct-Dec) and other wet seasonal parameters over Kitale Meteorological Station.

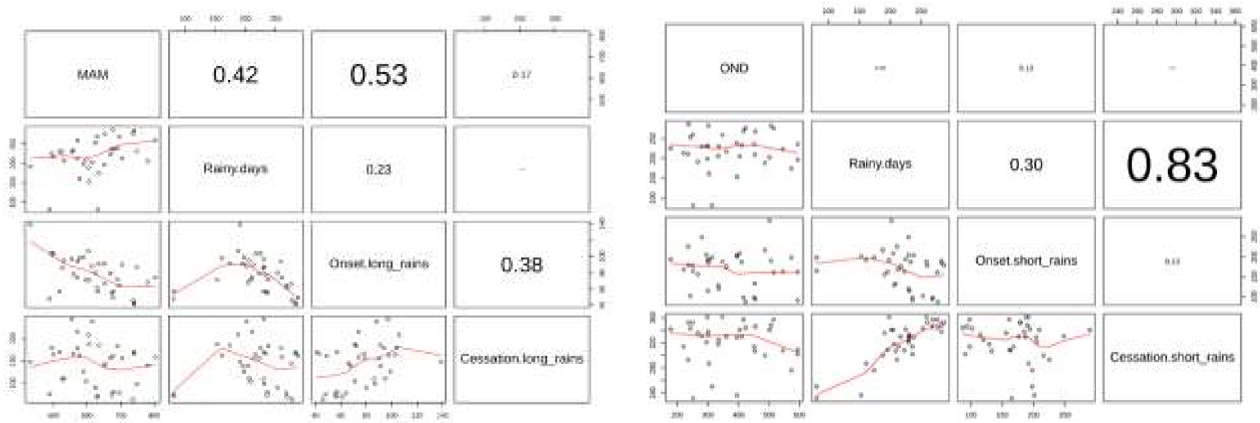



Figure 5.58: Paired scatterplots showing correlations between main rainy seasons ((Mar -May & Oct-Dec) and other wet seasonal parameters over Bukembe.

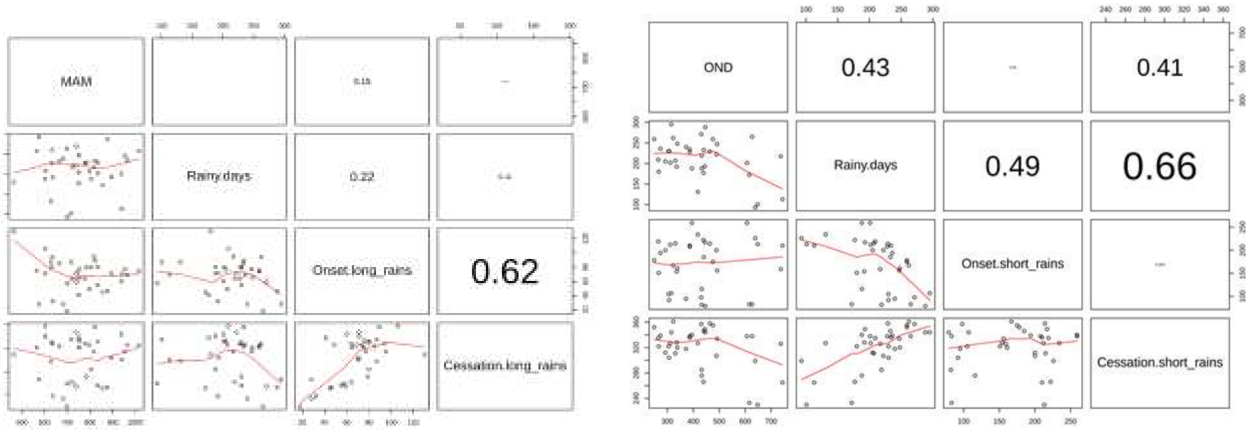



Figure 5.59: Paired scatterplots showing correlations between main rainy seasons (Mar -May & Oct-Dec) and other wet seasonal parameters over Kakamega Meteorological Station

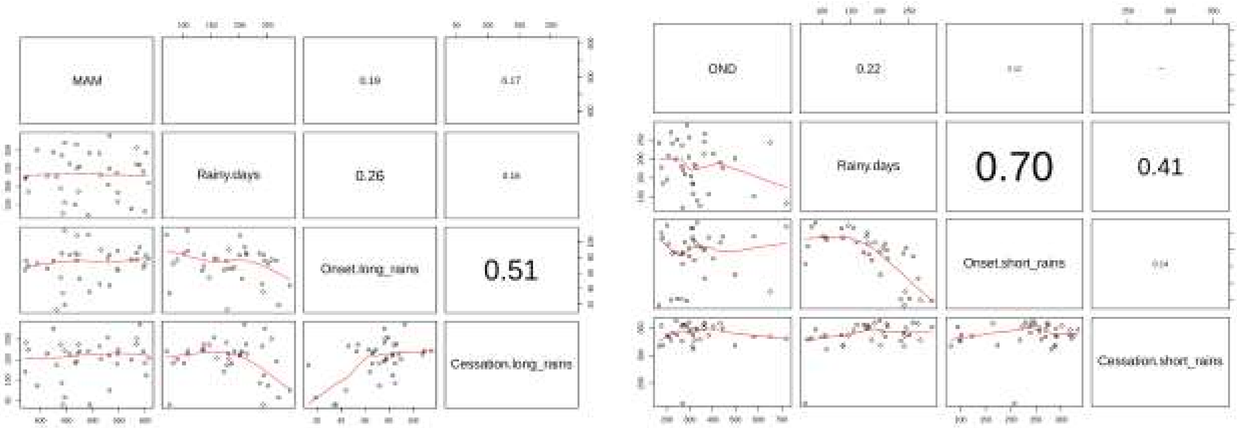



Figure 5.60: Paired scatterplots showing correlations between main rainy seasons (Mar -May & Oct-Dec) and other wet seasonal parameters over Port Victoria Mission Station

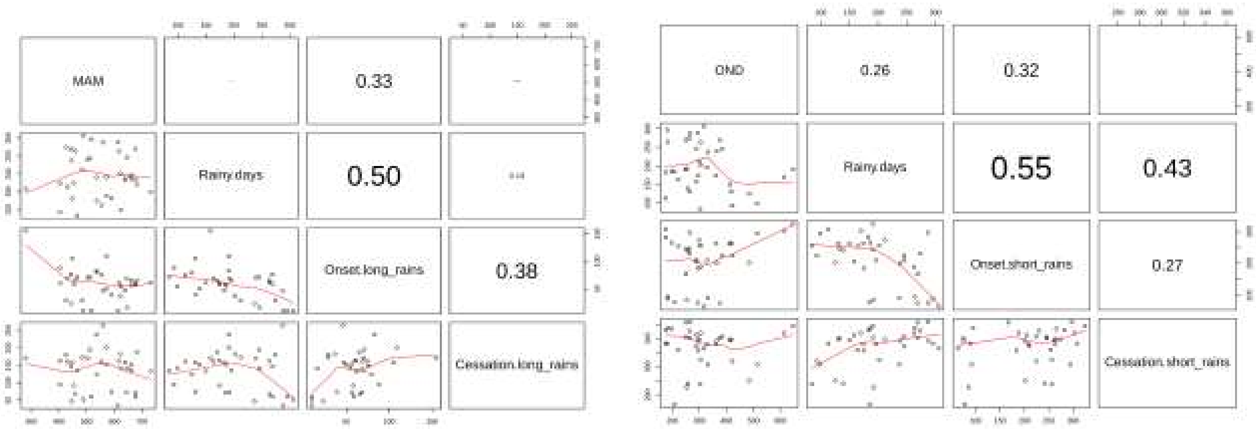



Figure 5.61: Paired scatterplots showing correlations between main rainy seasons (Mar -May & Oct-Dec) and other wet seasonal parameters over Kisumu Meteorological Station

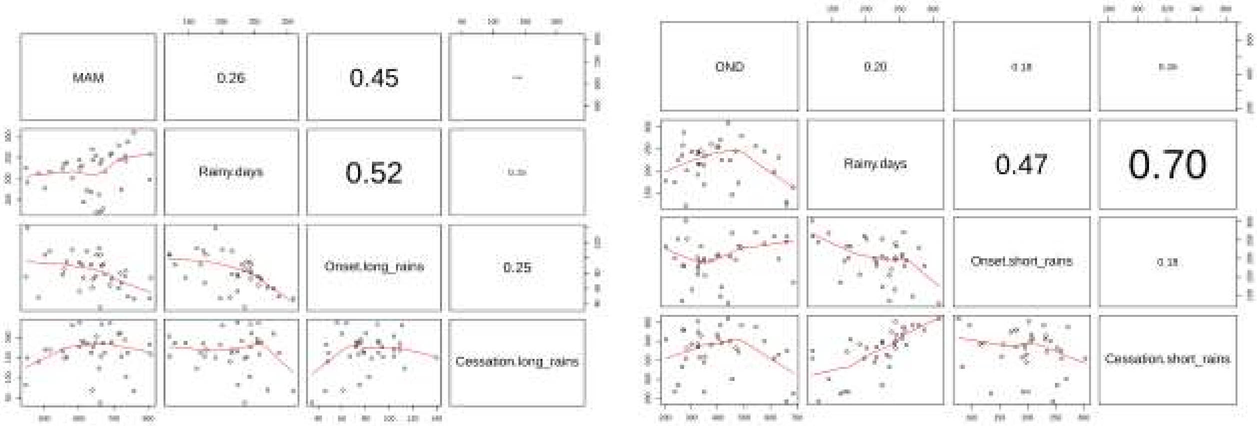



Figure 5.62: Paired scatterplots showing correlations between main rainy seasons (Mar -May & Oct-Dec)  and other wet seasonal parameters over Sangalo Institute Station

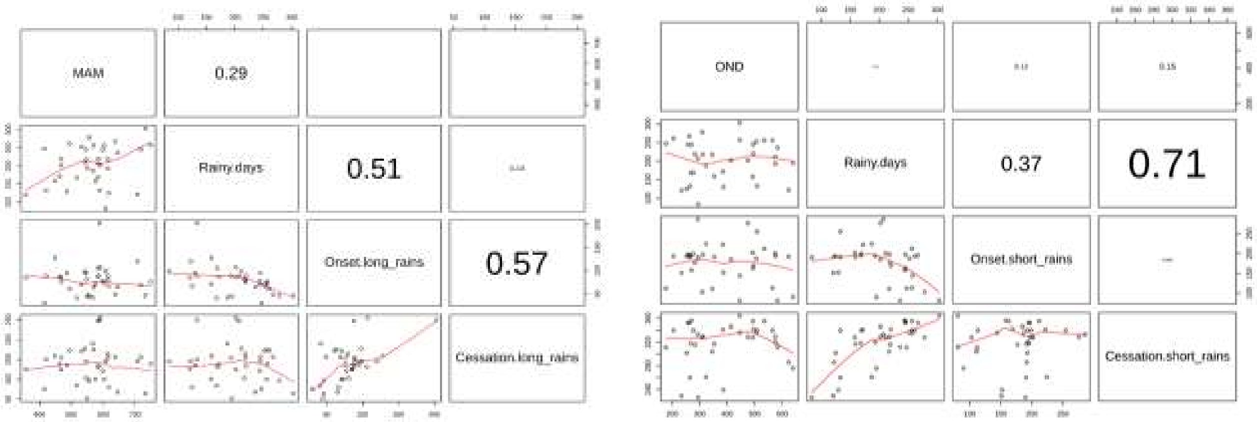



Figure 5.63: Paired scatterplots showing correlations between main rainy seasons (Mar -May & Oct-Dec) and other wet seasonal parameters over Kimilili Metereological Station

### 5.2.5 The Overal Climate Trend in Lake Victoria Basin of Kenya

The region of Lake victoria basin is fairly wet throughout the year. However, the relative wetness of the basin exhibited spatial-variation linked with the lake's compounded climatic set-up characterized by wobbling landscape, position of intertropical-convergence-zone furthest on the southern hemisphere (Camberlain et al.,2001) as well as increased humidity owing to its lake-proximity (Indeje et al, 2000). Study findings indicated March - May; October - December rains as dominant rainy seasons. Ongoma et al. (2018) documented that the March – May; October - December rains corresponded to a 42 percent; 25percent of the total basin's yearly rainfall. This finding is further supported by Nicholson (Nocholson, 1996; cited by Kizza et al., 2009), who reported positive trends for Mar -May rainfalls in the basin earlier. The result indicated positive trends for Mar -May (Long) rainfall with increased patterns during Oct-Dec rain-seasons noted across the weather-stations. However, the finding were unable to validate the Basin's two- three milimeter yearly-rainfall increase earlier established by Ongoma et al. (2018). The General Circulation Models assessment by Stoner et al. (2009), had earlier revealed that such discrepancies in climate results could be attributed to overestimation of seasons rainfall by climate models which, exhibited a higher seasonal rainfall peak, hence an increase in annual rainfall. Another discrepancy could be due to climatological years overlap in the data source which result into different findings (Kizza et al., 2009).

Rainfall variability between the years 1900-2000 was observed to be due to El Niño episodes and climate variability sensitivity (Hulme, 1992). For instance, the 1997 extreme rainfall record (Bell & Halpert,1998) coincided with the El Niño episode recorded that year in region. Furthermore, dry season experienced during the last decedes was attributed to the La Niña and El Niño teleconnection in the region (Anyamba et al., 2002). The onset and cessation of rainfall in regions that covers LVBK has been investigated in earlier researches (Dunning, et al., 2016; Camberlin & Okoola, 2003). A built consensus seem to suggest that the Mar-May onsets commenced on 25$^{th}$ of March while it was expected to end on the 21$^{st}$ of May and the inter annual variabilition expected to range btetween 14.5 days and 10.3 days respectively. This study however, found at least 50% variability in the beginning of Mar -May rains within the projected range 50 - 100 Julian days which revealed a delay too early to mid-April and, and the at least 30% variability in the cessations of short rains within the established range of about 100 to 200 Julian days, which implied the rains cessations occurred much earlier than expected. This significantly reduced the numbers of rainy days hence likely to affect the general ecology of the region and impact soil moisture availability that supports human livelihood in the region (Wabwire et al., 2020). The link between rainfall variation and variability in cessation and onset of rain periods has been recorded across Modified-Equatorial Eastern Africa covering Kenya and Tanzania's North Eastern regions. Additionally, to expound on variability of inter-annual-seasonal rains, onsets and cessations in everyday rainfall data for 3-agro-ecological areas have also been documented (Camberlin & Okoola, 2003).

From the finding it is clear that temperature followed rainfall trends. A significant increase in temperature within the basin was observed by Wabwire et al. (2020) in all agro-ecological zones under study. The mean increased between 0.5ºC - 0.7ºC and 0.7ºC and 1ºC for minimum and maximum temperature respectively. The finding of the study seems to be consistent with early findings recorded by (Anyah & Qiu, 2012). Station closer to Lake Victoria recorded a higher increase in means of maximum temperature, while those stations in basins' highlands recorded a high increase in means of minimum temperature.

## 5.3 Climate Change Effect on Rural Household Livelihood in the Lake Victoria Basin of Kenya

There are several climate change characteristics that effect on household livelihoods in a rural setting. These characteristics include; the age, wealth, prior knowledge on changes of climate, social capital and ago-ecological settings (Deressa et al., 2011). This section, therefore examined the above characteristics in regard to the residents of Lake Victoria Basin of Kenya.

### 5.3.1 Demographic Characteristics of the Household Respondents

Demographic features for any household play a vital role in the assessment of household livelihoods which are climate controlled. They are important characteristics that can be used to reveal the household climate risks and the efficacy of adaptation strategies. The household respondents comprised of 51.8% male and 48.2 % female respondents. A majority of the respondents were over forty years (Figure. 5.64).

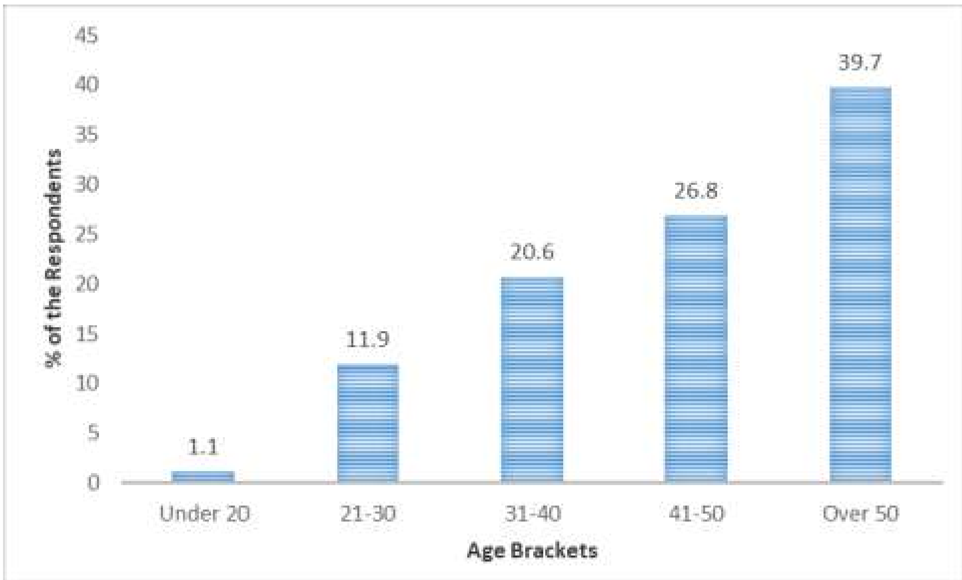



Figure 5.64: Age Bracket of the Respondents (Source: Field Study, 2017)

Monogamous marriage was the most common form of union with 65.8% in the region, distantly followed by polygamous marriage with 15.1%. Other marital status included 9.2% for single, 8.3% for widowed and, 1.2% for either separated or divorced. A significantly low percentage (0.4%) of the respondents could not disclose their marital status; a negligible number that could not influence findings of the study.

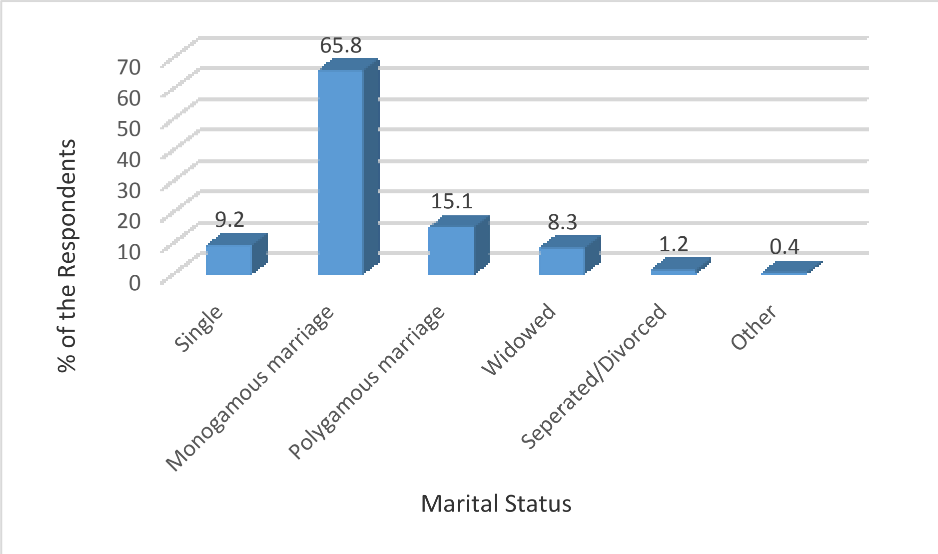



Figure 5.65: Marital Status of the Respondents (Source: Field Study, 2017)

A majority of the respondents had acquired formal education 89.3%. The study established that 38.3% had primary education, 32% secondary education, 17.6% and, 5.7% technical or vocational training as shown in the Table 5.1.

Table 5.1: Respondents' Education Level

| Education Level | Frequency | Percent (%) |
|---|---|---|
| Primary | 216 | 38.3 |
| Secondary | 185 | 32.8 |
| Tertiary | 99 | 17.6 |
| Technical/Vocational | 32 | 5.7 |
| none | 32 | 5.7 |
| Total | 564 | 100.0 |

(Source: Field Study, 2017)

The result of the finding indicated that some of respondents had more than one occupation for household livelihood. These included farming and livestock rearing (32.8%), farming and trading (17%) and, livestock rearing and salaried work (5.9%). Other respondents had a single occupational activity which included farming (20%), livestock rearing (3%), fishing (3.9 %), trading (8.7%) and, salaried work (6.7%) (Table 5.2).

Table 5.2: Respondents' Occupational Activities

| Occupation | Frequency | Percent (%) |
|---|---|---|
| Farming | 113 | 20.0 |
| Livestock rearing | 17 | 3.0 |
| Fishing | 22 | 3.9 |
| Trading | 49 | 8.7 |
| Salaried Work | 38 | 6.7 |
| Farming/ Livestock rearing | 185 | 32.8 |
| Farming/ Trading | 96 | 17.0 |
| Fishing/ Livestock rearing | 4 | 0.7 |
| Farming/ Livestock rearing/ Salaried work | 33 | 5.9 |
| Others | 7 | 1.3 |
| Total | 564 | 100.0 |

Source: Researcher 2017

### 5.3.2 Climate Change Effects on Gender roles, Marital status, Family Size and Education Level

The findings of this study, established a significant association between climate change, gender roles, family size and educational level. The result of the study showed that all the responses had a P-values that were less than the chosen significance level α = 0.005, except for marital status (Table 5.3).

Table 5.3: Significance level of Climate change Association

| Association | P-Value | df | Significance (2-sided) |
|---|---|---|---|
| Gender roles | 13.513 | 35 | .000 |
| Marital Status | 58.460[a] | 35 | .008 |
| Family Size | 71.600[a] | 35 | .000 |
| Educational Level | 28.444[a] | 8 | .000 |

Marital status is an important social factor that determines household livelihood. Panthi et al. (2016) asserted that marital status determines the family size. Tucker et al. (2015) in their study established that marital status affected the social demographic characteristics increase vulnerability to climate change.  The gender parities in climate change hampered women's opportunities to access resources such as land and credit facilities (Nabikolo et al., 2012), while Alam et al. (2015) and (Kristjanson et al., 2017) further concurred with the fact that women and male suffer disproportionately due to their place in society.

The polygamous union is likely to comprise large family sizes, which puts pressure on available livelihood resources to adequately meet their needs. In the LVBK, the natural capital is largely climate controlled and any disturbances would exacerbate the climate effect at the household level. Sufficient grounds have been laid that recognize high climate vulnerability among the single headed households as compared to those families with both parents (Khisa et al., 2014; Oluoko-Odingo, 2011).

While it is also true that climate change is bound to affect everyone, increased episodes of droughts, floods, and diseases (IPCC, 2017) climate risk is likely to increase depending on educational level. According to Wamsler (2012), education plays a fundamental role in the knowledge aboutclimate change understanding, and their related risk as argued by education equips an individual with a deeper understanding of climate change adaptation strategies. Nabikolo et al. (2012) affirmed that people with formal education had the ability to respond better to climate risk, hence reducing their vulnerability. The household occupation among rural households contributes immensely to the livelihoods of the majority of the rural population (Mikalitsa, 2010). It also influences household climate change adaption and mitigation (Poudel et al., 2017) with the underlying supposition that diversification of family sources of income played a vital role in the household's climate change adaption. The households among the rural poor areas have occupations revolving around rain-fed agriculture and with the absence of credit facilities, the climate risks are likely to escalate among many households.

### 5.3.3 The Impact of Change Effect on House Livelihoods

Table 5.4: Showing Households Response on Climate Changes Effect on Rural Livelihoods

| **Climate change effect** | Frequency | Percent | Cum. |
|---|---|---|---|
| No | 48 | 9 | 9 |
| Yes, but not severely | 284 | 53 | 62 |
| Yes, severely | 205 | 38 | 100 |
| Total | 537 | 100 | |

The study findings revealed a significantly low number of respondents did not experience the effect of climate change, out of the 537 households sampled across the different agro-ecological regions 48 households (9%) indicated that climate change had no effect on rural livelihood, 284 households (53%) indicated effects of climate change though were not severe, while 205 households (38%) indicated severe effected by climate change (Table 5.4).

The study findings exposed frequent and prolonged severe droughts (35%) as the most perceived change effect in all the household respondents. The study also established other climate changes that include; an increased temperature (28%), changes in rainfall onset and cessation (13%), increased hailstones incidents (8%), an outbreak of crop pests and diseases (7%) and, strong winds (6%) was the least effect by climate change (Table 5.5). The study findings resonated with an earlier study by Wamsler (2012), which acknowledged that people have the ability to perceive changes in climate that affect them.

According to Field (2014), climate change effects are more visible in the third world countries as compared to the developed countries. It is imperative, therefore, that climate extremes generated by changes in climate resulted into some as well as cause crop failure and increase the frequency of droughts. These climate changes could potentially disrupt the household livelihood functions. The households' awareness of the climate change effect therefore, underpinned the quest to of this study to establish how many households adapt to looming changes.

Table 5.4: Household response on Climate Changes related effect that affect livelihood

| Location | Increased hailstones incidences | Increased temperature | Frequent and prolonged severe droughts | Strong winds | Outbreaks of crop pests and diseases | Change in Rainfall Onset and Cessation | No changes experienced | Total |
|---|---|---|---|---|---|---|---|---|
| **Tambua** | 15(35%) | 50(32%) | 58(29%) | 8(24%) | 3(7%) | 10(14%) | 6(30%) | 150(27%) |
| **South East** | 7(16%) | 28(18%) | 82(42%) | 1(3%) | 8(19%) | 6(8%) | 0(0%) | 132(23%) |
| **Kamusinga** | 16(37%) | 28(18%) | 35(18%) | 22(65% ) | 18(42%) | 30(41%) | 14(70%) | 163(29%) |
| **Twiga** | 5(12%) | 51(32%) | 22(11%) | 3(9%) | 10(23%) | 28(38%) | 0(0%) | 119(21%) |
| Total | 43(8%) | 157(28%) | 197(35%) | 34(6%) | 39(7%) | 74(13%) | 20(4%) | 564(100%) |

Source: Researcher 2017

The study findings showed that climate change effects imposed serious challenges on the rural household livelihood in the LVBK (Table 5.5). The study finding further, indicated that the significant number of respondents had observed the effect on subsistence farming (68.7%) as the main climate change effect. A slightly lower number of respondents had noticed the effect on livestock (14%), increased water stress (7.2%) (Plate 5.1 and 5.2), reduced milk production (3%), increased cases of human disease (2.7%), which tied with Low fish count (2.7%) and, damage on a household property (1.7%) was the least effect of climate change identified by the respondents from both Tambua and Twiga locations. The result also showed that some respondents had noticed an erratic change in food and livestock prices (14%), while some respondents had observed water stress (7.2%).

Table 5.5: Climate Chnge effect on Household livelihoods

| Climate change effects at a household level | Tambua | South East | Kamusinga | Twiga | Total |
|---|---|---|---|---|---|
| Effect on Subsistence farming | 92 (28.3%) | 75(23.1%) | 79(24.3%) | 79(24.3%) | 325 (68.7%) |
| Effect on livestock | 5(7.6%) | 3(4.5%) | 55(83.3%) | 3(4.5%) | 66 (14 %) |
| Increased water stress | 3(8.8%) | 15(44.1%) | 12(35.3%) | 4(11.8%) | 34 (7.2%) |
| A decline in milk production | 3(21.4%) | 3(21.4%) | 4(28.6%) | 4(28.6%) | 14 (3%) |
| Increased cases of human disease | 0(0.0%) | 1(7.7%) | 9(69.2%) | 3(23.1%) | 13 (2.7%) |
| Low fish count | 0(0.0%) | 13(100%) | 0(0.0%) | 0(0%) | 13(2.7%) |
| Damage on household property | 1(12.5%) | 0(0.0%) | 0(0.0%) | 7(87.5%) | 8(1.7%) |
| Total | 104(22%) | 110(23.3%) | 159(33.6%) | 100(21.1%) | 473(100%) |

Source: Field Data (2017)

Plate 5.1 Open water pan in South East Location in South East Location

5.2 Rainwater harvesting in Kamusinga Location

The study further established that climate change on resulted into reduction of household food supply by 50%, for subsistence farmers which majority of the respondents acknowledged was severe. Crop failure was attributed to overdependency on rainfed agriculture and damage by hailstones (Figure 5.66). Other causes include pests and diseases and, drought.

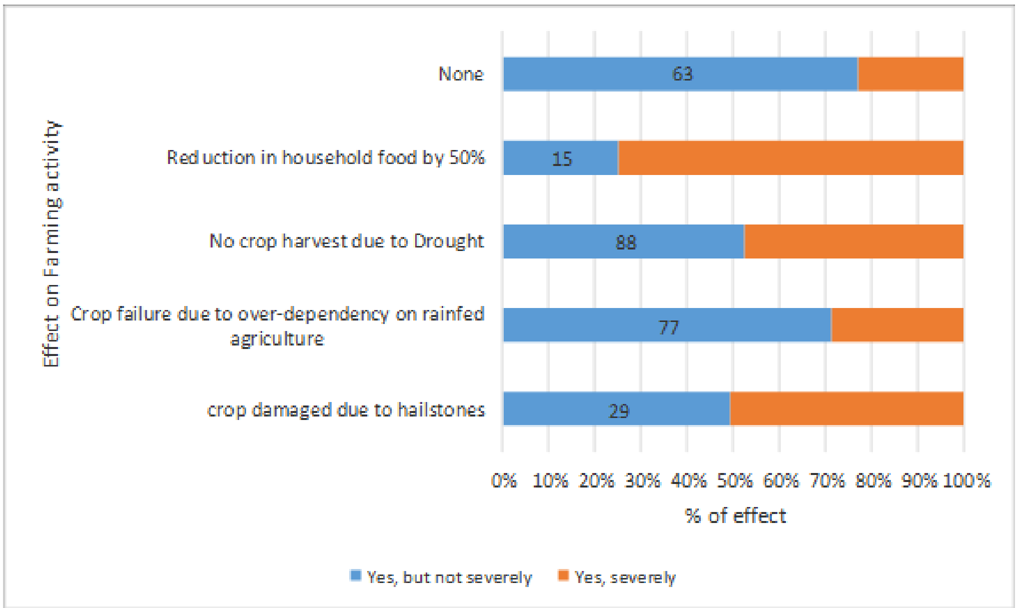



Figure 5.66: Showing effect of changes in Climate related events on household farming activity

One household respondent observed that the reasons for decreased crop production were due to crop and pest infestation that has become so common in recent times. On the same issue, another household respondent insisted that the change in rainfall patterns has made it hard to predict the rainfall on-set. The normal planting season is marked by delayed rains which result in poor germination. Harvesting is also affected since nowadays, there are too much rains that affect crops. Accordingly, another respondent stated that 'major crop losses are now witnessed during harvesting period that has too much rains. Instead of crops drying during harvesting, they actually rot in the field.

Plate 5.3 Maize farm damaged due to the dry spell in South East location

Plate 5.4 A maize farm destroyed by hailstorms in Tambua Location

The study further established that the months between March and May (40.6%), when households experienced stress on food security. These months coincides with the rainy season in the basin where most households are planting their crops (Wabwire at al. 2020) Other respondents indicated June, July, and August (JJA) (34.8%), with the majority being Lower Midland Zone. Still, some respondents indicated December, January, and February (19.3%), where South East and Tambua locations prominently featured, while the least number of the respondents referred to September, October, and November (5%) (Table 5.7).

Table 5.7: Months of Occurrence of Food Insecurity Among the Households in LVBK

| Location | Months of Occurrence | | | | |
|---|---|---|---|---|---|
| | JF | MAM | JJAS | OCT-DEC | Total |
| Tambua | 36(37.1%) | 46(47.4%) | 13(13.4%) | 2(2.1%) | 97(23.2%) |
| South East | 33(34%) | 16(16.5%) | 34(35.1%) | 14(14.4%) | 97(23.2%) |
| Kamusinga | 12(9.2%) | 97(74.6%) | 16(12.3%) | 5(3.8%) | 130(31.1%) |
| Twiga | 0(0%) | 11(11.7%) | 83(88.3%) | 0(0%) | 94(22.5%) |
| Total | 81(19.3%) | 170(40.6%) | 146(34.8%) | 21(5%) | 418 (100%) |

Source: Field Data (2017)

Several factors shape households' perception of climate change (Deressa et al., 2011); consequently, no single factor such as poverty could be attributed to how they view the climate change effects in their livelihoods. It further confirmed a consistent view that women can be more vulnerable than men to climate change (Djouudi et al., 2016; Arora-Johsson, 2011). Eastin (2008) study on climate change and gender equality in developing countries further alluded the fact that the existence of gender disparities in climate change vulnerability was a clear mirror reflection of gender inequality in many developing states.

In Africa for instance, Deressa et al. (2011) established that while there exist inequalities in the ownership and control in household assets with the male being advantaged, women still play a crucial gender role in ensuring that most livelihood need are met.  Climate change effects on the hand increase stress on food and water access that further undermine women capacity to achieve economic freedom, improve human capital and preserve health welling being. Marital status is an important social factor that determines household livelihood. Panthi et al. (2016) asserted that marital status determines the family size. Tucker et al. (2015) established that marital status affected the social demographic characteristics increases vulnerability to climate change. Nabikolo et al. (2012) on the other hand affirmed that gender parities in climate change hampered women's opportunities to access land and credit facilities. While Alam et al. (2015) and (Kristjanson et al., 2017) further concurred with the fact that women and male suffer disproportionately due to their place in society. The study findings, however, revealed that marital status did not affect the household perception of climate change effects.

While the science of climate change is well articulated across the existing literature (IPCC, 2007; IPCC 2001; Field, 2014), a study by Eastin (2018) revealed that there is no sufficient knowledge on climate change effect in developing countries. Eastin's (2018) study shows that climate change continues to be a pressing issue among many rural households. It was notable that households' perception on climate change effects and adaptation strategies are shaped by many households' underlying factors (Poudel et al., 2017). In this study, households with formal education were more informed of climate change, similar observation was revealed in El Salvador and Brazil where schooling played an increasing role in the communities' adaptive capacity (Wamsler et al., 2012). A significant  of rural household heads in the Lake Victoria Basin of Kenya perceived significant changes in climate which affected their livelihoods. The present study's findings resonate with earlier finding on the spatial and temporal characteristics of rainfall which, established variation in rainfall onsets and cessations, and, frequent droughts in the recent past (Wabwire et al., 2020).  Climate change continues to manifest its effects among the local poor affecting their household income, increasing food insecurity and vulnerability (Khisa et al., 2014), contrary to sustainable livelihoods for rural poor postulated in sustainable livelihood approach (Scoones, 2015).

The study established that poor household especially those that depend on small scale agriculture are more vulnerable to negative climate change effects (Berman et al., 2015). The rural household, therefore, were involved in more activities such as; small business, agricultural productivity and fishing so as to minimize the effect. A study by Kolawole et al. (2016) observed that climate change adversely affected rural households' agricultural productivity and other livelihood strategies. Keshavarz et al (2017), further established that agriculture was the main rural livelihood sources in the developing countries which, are inherently sensitive to climate change.

Shepardson et al. (2012) on the other hand concluded that there is still much needs to be done to bridge the realities of the science of climate change and society as a means to inform future climate researchers. The IPCC (2014) Report, indicated that climate change has a direct effect on sectors that are climate dependent and, further hampered by poverty. The effects of changes in climate cannot be overemphasized (Payne et al., 2004; IPCC, 2007; IPCC, 2014). Furthermore, Shobha et al. (2017) reiterate that the effect of climate change is exacerbated by poverty since the people living in developing areas have a low adaptive capacity

The study findings seemed to agree with earlier studies by Arnell et al. (2002). The mentioned studies established the correlation between climate change and crop yield. Kotir (2011) observed climate change and its potential future pathways are likely to reduce agriculturally suitable areas, vary the length of growing seasons and reduce the potential crop yield. Furthermore, IPCC (2014) affirmed that changes in climate are projected to reduce crop production, thus causing stress in food security. While it is true that climate change affects crop yield, its effect on food security is not only complex but also difficult to discern. The study by Thompson et al. (2010) alluded to three aspects of food security that are highly impacted by climate change, they include availability, access, and utilization.

FAO (2009) articulated food security as a condition where the entire human population, at all time, have sufficient access, safe, and nutritious food that meet dietary needs and preferences wellbeing. The household food security is indirectly or directly jeopardized by climate change (Oluoko-Odingo, 2011). The food security is affected directly when weather elements such as rainfall variability affect the crop productivity and indirectly, when the food prices go up and household food access is comprised.

## 5.4 The Household Adaptations Strategies

There are several strategies of rural households to adapt to climate change. This study revealed a significant number household respondents planted drought resistant crops (30%), diversified agricultural activities (28%), while still others destocked livestocks (21%). Other strategies included; sourcing credit facilities (7%), constructing water storage facilities (7%), diversified family diet to other foods (3%), joined a CBO/self-help groups (2%), shifting to other livelihood activities and proper planning (1%) and, still others indicated that they used good house asset management (1%) (Figure 5.8).

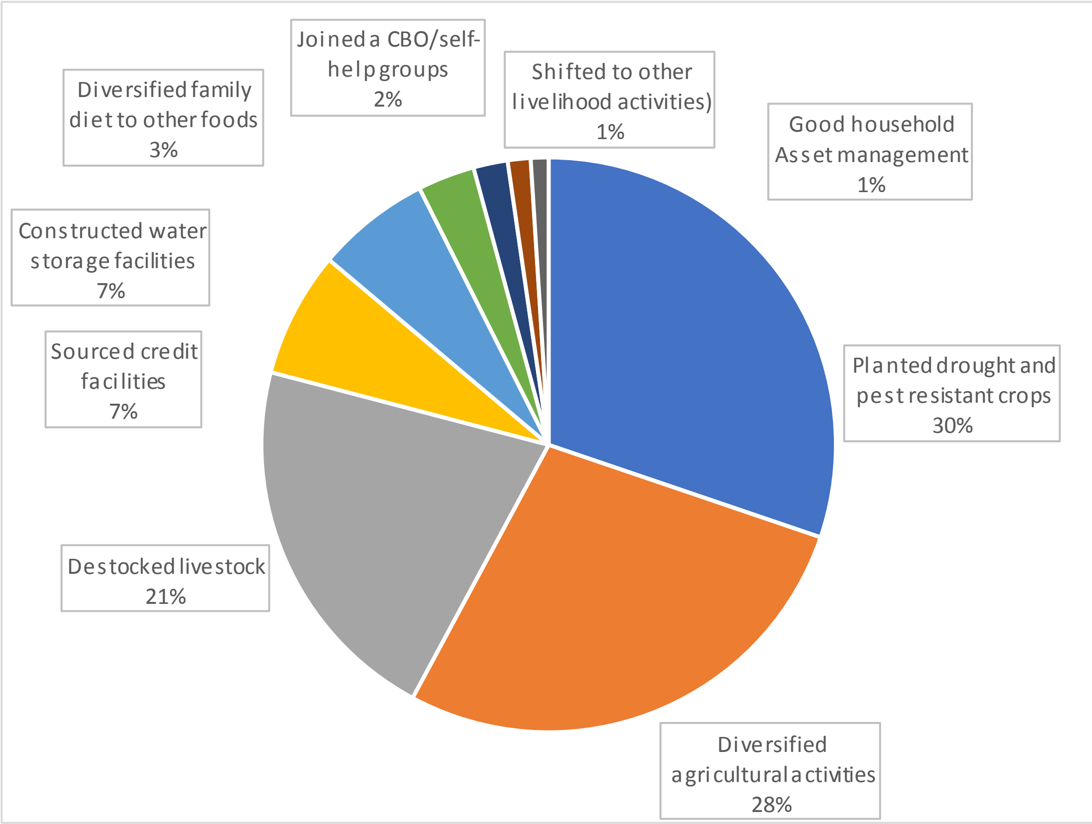



Figure 5.67: Rural Household Climate Change Adaptation Measures

(Source: Researcher 2017)

The climate change adaptation is geared toward helping households deal with the current and future climate change effects. The findings indicated that households within the LVB of Kenya employed autonomous adaptation, which commenced immediately, felt the effects of climate change or variability on their socio-economic welfare. The results established that the majority of the households employed the later.

Table 5.8: Chi-Square Test for Adaptation Measure and their Significance

| Chi-Square Tests | Value | df | Asymptotic Significance (2-sided) |
|---|---|---|---|
| Pearson Chi-Square | 549.985[a] | 9 | .000 |
| Likelihood Ratio | 643.012 | 9 | .000 |
| Linear-by-Linear Association | 496.281 | 1 | .000 |
| N of Valid Cases | 564 | | |

Source: Researcher (2018)

This study established that households relied on the stakeholders for planned adaptation strategies. Such measures are more concerned with moderating the potential future climate effects or impact through premeditated policy actions that were meant to achieve desired outcomes. The planned adaptation measures by the government, key stakeholders, that was vital to households included, provide farm inputs (fertilizers, seeds) to farmers; initiate irrigation; provide accurate weather forecasting; educate household on better agricultural practices (extension services); drill water and pipe it to residents and in some cases constructed water pan (Plate 5.7); educate the public about climate change; provide credit facilities; provide relied on relieve services; fund projects/programs that are climate change-related to households; provide financial planning on climate change related projects; reduce prices of commodities and; improve channels efficiency that targets vulnerable households.

Plate 5.7: A girl fetching water at a constructed open water pan in Banda area of  South East location, Migori County

The need to leverage finances both from the private and public sectors for effective climate adaptation strategies at the household cannot be underestimated.  The effort is, however, hampered by declining private finance sources that targets household (Buchner et al., 2014). This has forced some households to sell their household properties as a way of coping with climate change. The results from the measure of a significance however did not show significant relationship between the sale of household properties and climate change adaptation (Table 5.10).

Table 5.10: Association between sell household properties and adaptation measure

| Chi-Square Tests | Value | df | Asymptotic Significance (2-sided) |
|---|---|---|---|
| Pearson Chi-Square | 13.370[a] | 4 | .010 |
| Likelihood Ratio | 16.398 | 4 | .003 |
| Linear-by-Linear Association | 8.016 | 1 | .005 |
| N of Valid Cases | 564 | | |
| a. 3 cells (30.0%) have expected count less than 5. The minimum expected count is 1.66. | | | |

(Source: Researcher 2018)

The study further established that stakeholders play a significant role in climate-related issues that affect household livelihood. Some of the roles established included: to initiate irrigation (21.6%); provide relied relief services (15.2%); provide farm inputs (12%); educate households on climate change (16.6%); drill water and pipe to households (9.8%); plant trees (REDDS) (9%); provide accurate climate information (6.8%); fund household projects/programs that relates to climate change (6%); regulate commodities prices (2.8%) (Figure 5.67).

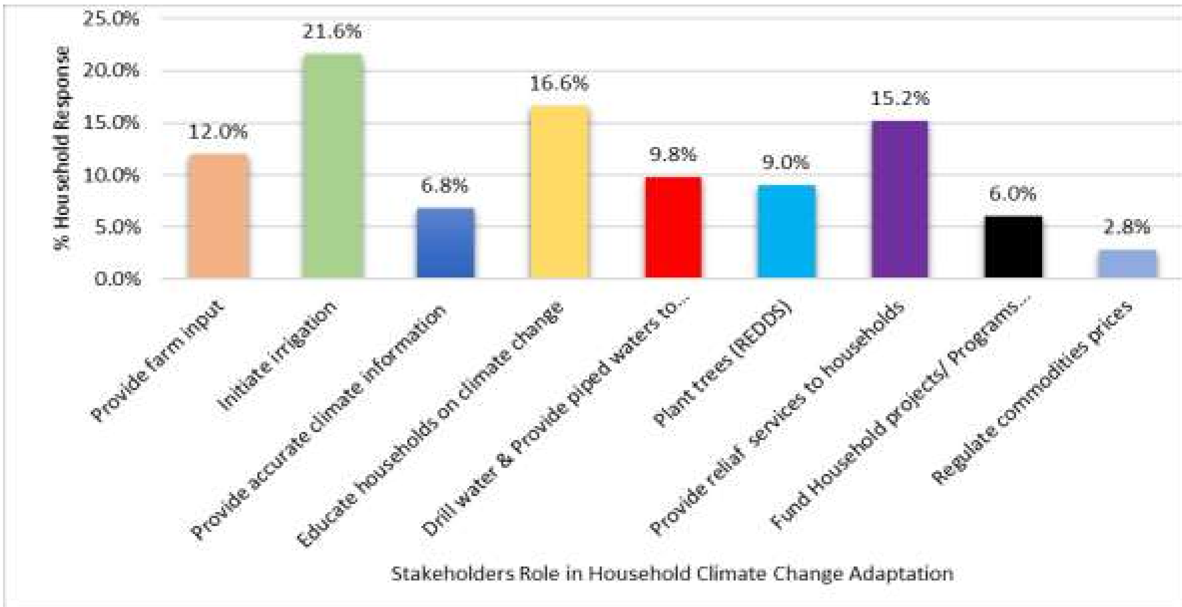



Figure 5.68: Stakeholders role in improving household livelihood

Several factors influence a household's to climate change adaptation. These factors included: the household head education level, family size, the gender of the household head, the agricultural extensional services, the credit facilities.

While available literature has given a fair amount of attention to climate change adaptation, A study by Mersha and Van Leerhoven (2016) established several barriers to climate change related to socio-economic and ecological factors. A well-integrated adaptation strategies can alleviate human livelihoods from the severity of climate change impacts (Alam et al., 2017). This study the People's ability to adapt to changes in climate influenced by family size, occupation, and wealth and social status. Ofoegbu et al. (2017) The sustainable climate change adaptation strategies are limited by socioeconomic characteristics such as life skills, educational level, health, functional infrastructures and communities' services. Mersha and Van Laerhoven (2016) further, suggested that differences in gender roles influenced the household adaptation choices. This is because adaptation measures are more likely to be driven by cultural, social, financial, and institutional barriers at a household level. Effective adaptation strategies require the proper understanding of the household perceptions of climate change.

The result of this study revealed that most households not only employed various adaptation measures, but also adopted a coping mechanism to manage the effects of climate change on their livelihoods. The adaptation measures and coping mechanisms included; planting drought and pest resistant crops; diversifying agricultural activities; destocking livestock; sourcing credit facilities; constructing water storage facilities; diversifying family diet to other foods; joining CBO/self-help groups and; shifting to other livelihood activities. In Ghana, most households engaged in crop diversification, non-farm jobs, some migrated to urban areas while still others resorted to extensive farming as a way of adapting to changes in climate (Dumenu and Obeng (2016), on Climate change and rural communities. The study emphasized the importance of local-level climate change vulnerability assessment and demonstrated the need for local area-specific actions/policies to reducing vulnerability and enhancing adaptation in rural communities. In Botswana households devised strategies of selection and preservation of drought-resistant and, early maturing seeds as a way of adapting to changes in climate. They also shift the farming calendars to overcome the erratic weather patterns (Kolawole et al. (2016). It is imperative that most communities engaged in adaptation strategies which include adopting new crop varieties, changing planting time, homestead gardening, planting trees, and migration (Alam et al., 2017). The climate change adaptation initiatives in households are more certain focused on improving people's socioeconomic conditions and the overall sustainable development of the community

## 5.5 The Potential Future Pathways of Climate

This study explored the future characteristic of rainfall onsets, cessations and rainy days in two distinct future climate periods; one centered around 2030 (2015 to 2045); here referred to as near future, and another centered around 2060 (2046 to 2075); here referred to as mid future). Both periods were assessed under climate model scenarios RCP 4.5 and RCP 8.5. This climate data used for future climate projection was extracted at each selected station from the nine climate models. Their average was computed in these two climate periods (since the average of the models captured the climate of the region well when we compared their historical versus observations).

The finding of onsets, cessations, and the rainy days for the historical period between 1981-2016 (Section 5.2.4.2) were compared with those in the near, mid and far future so as to investigate the possible future pathways. The onsets, cessations, and rainy days were computed for both medium mitigation of carbon emissions scenario RCP 4.5 and high carbon emissions scenario RCP 8.5 using data available from CORDEX models. The findings of the study were presented on the side-by-side bar plots to enable comparison of patterns.

### 5.5.1 Potential Future Seasonal Rainfall Trend

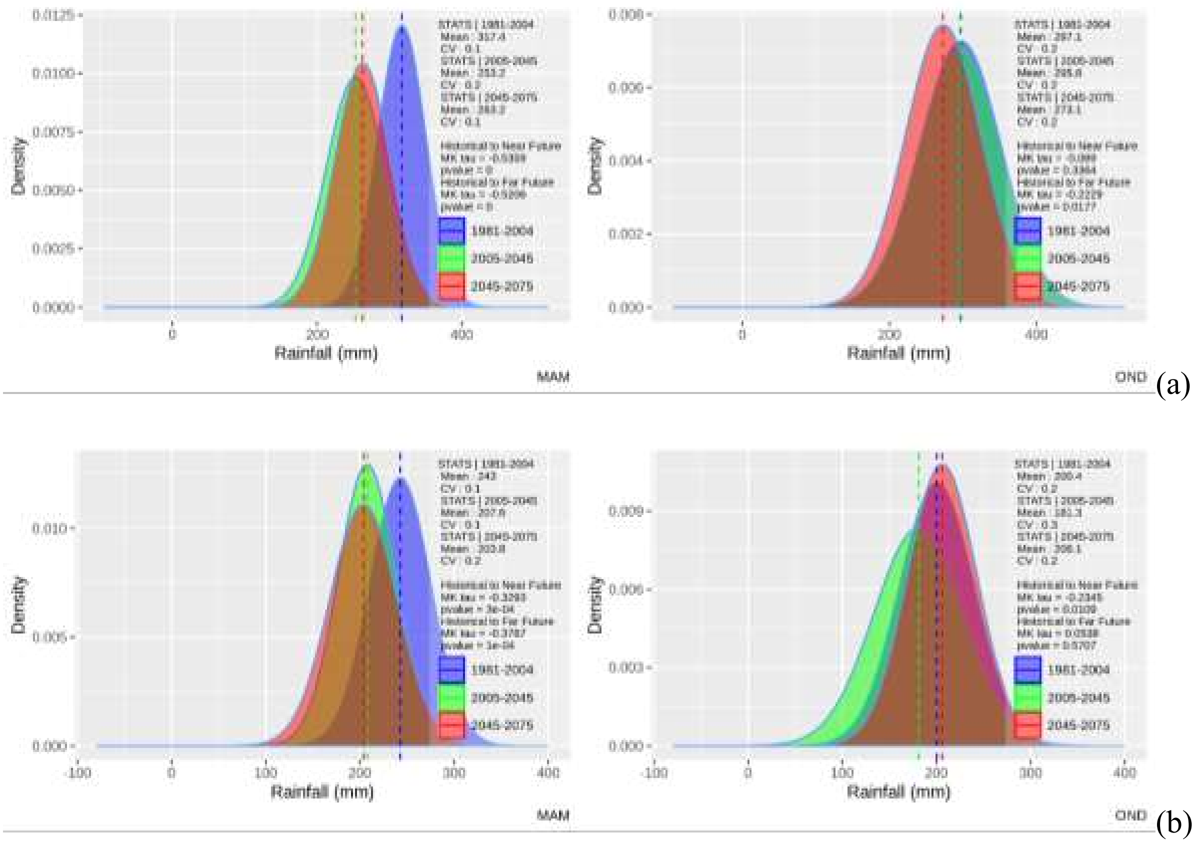
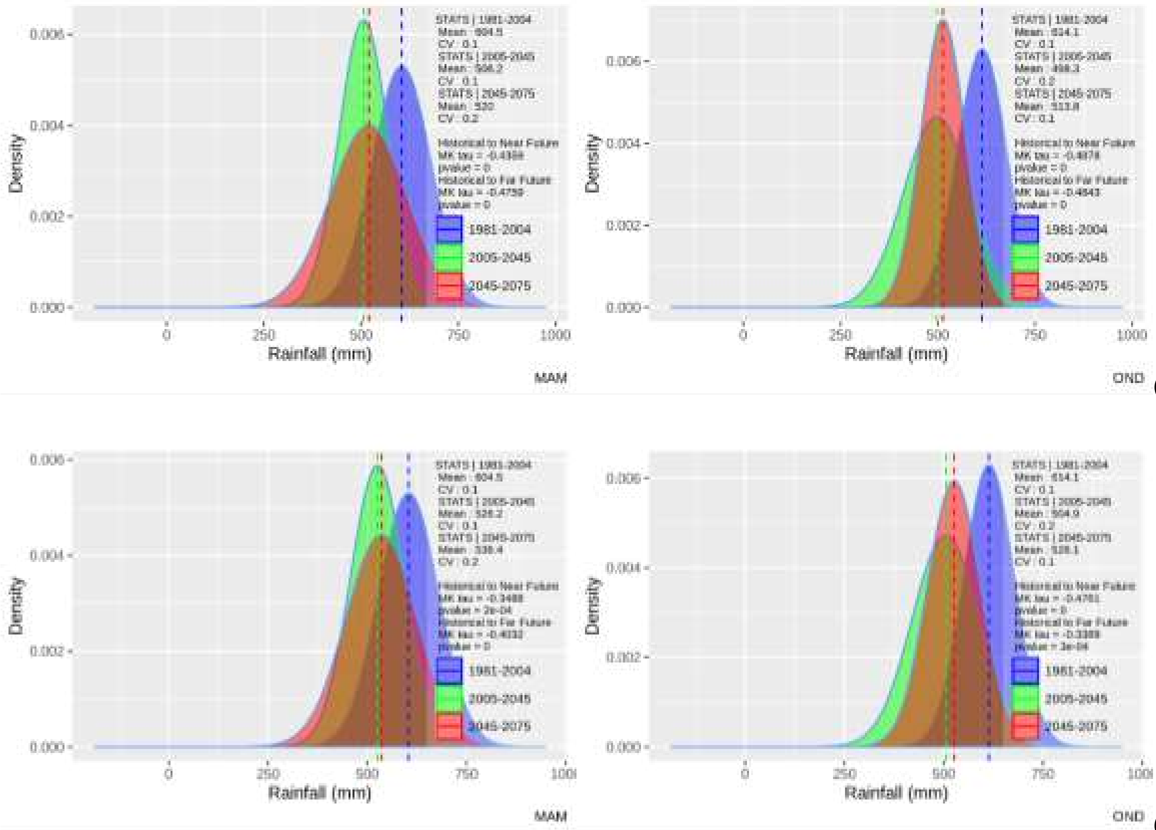



Figure 5.68 Distribution plots Showing seasonal rainfall projection over Bukembe for period between (1981 - 2075) under RCP 4.5 9 (a) and 8.5 (b) emission scenario.

The result in figure 5.68, the mean rainfall for Mar-May rains is projected to decline in near future (between 2005-2045) by 64.2 mm down from 317.4 mm mean in historical period and further drop by 54.3 mm in far future (between 2045-2075). Also, the Oct-Dec mean rainfall is projected by the models to decrease by magnitude 1.1 mm down from 297mm and a further drop of 24.0mm in the near future and far future respectively under RCP 4.5 scenario. Similarly, suppressed rainfall is projected under the RCP 8.5 scenario, albeit with smaller margins during the long rains (Mar-May) season but mixed behavior in the changes during the short rain (Oct-Dec) season. The mean for Mar-May rains is projected to decline by 35.4

mm in the near future (between 2005-2045) and 39.2 mm in far future (between 2045-2075); while Oct-Dec rains are projected to slightly decline by 9.1 mm in the near future and an increase of 1.7 mm for far future.  In all the emission scenarios, a declining trend was observed for both the Mar-May and Oct-Dec rains. Through the three climatological periods, those expected shifts are statistically significant at standard 95% confidence interval, as observed from the p-value of fitted monotonic trend less than 0.05  (Figure 5.68).



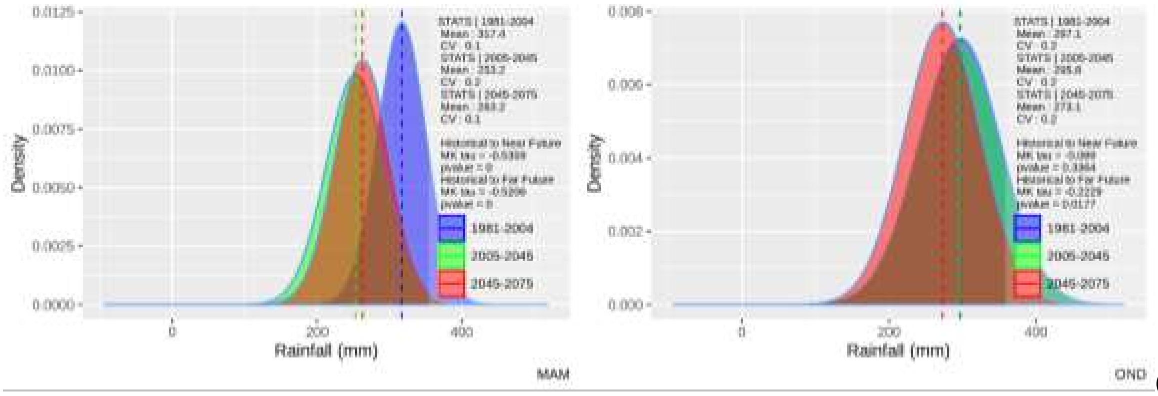

(a)

(b)

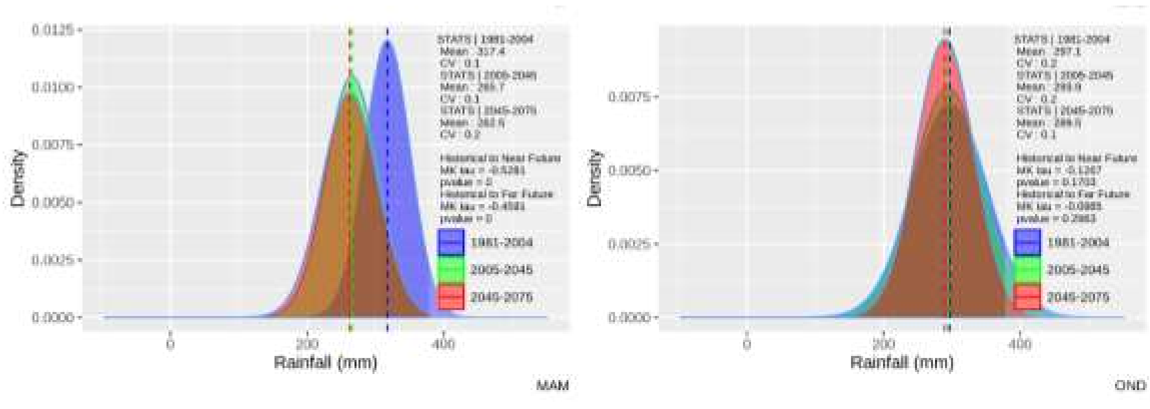
Figure 5.69 Distribution plots Showing seasonal rainfall projection over Kakamega Meteorological Station for period between (1981 - 2075) and (1987 - 2016) under RCP 4.5 9 (a) and 8.5 (b) emission scenario.

At Kakamega Meteorological Station, the mean rainfall for Mar-May rainfall is projected to decline in the near future (between 2005-2045) by 98.3 mm down from 604.5 mm mean in the historical period and further drop by 84.0 mm in far future (between 2045-2075). Also, the OCT-DEC mean rainfall is projected by the model to decrease by a magnitude of 115.8

mm and further by 100.3 mm in the near future and far future respectively under the RCP 4.5 emission scenario. Likewise, suppressed rainfall is projected under the RCP 8.5 emission scenario, although with higher margins during the Mar-May rainfall by 78.3 mm in the near future (between 2005-2045) and 69.1 mm in far future (between 2045-2075) from the current observed seasonal mean rainfall. A smaller decline margin is projected for the Oct-Dec rainfall by 9.1 mm and 1.7 mm from the mean of 614.1 of the historical mean for the near future and far respectively. In all the emission scenarios, a declining trend for both the Mar-May and Oct-Dec rainfall was observed at Kakamega Meteorological Station. From the study, the three climatological periods, those expected shifts are statistically significant at the standard 95% confidence interval, as observed from the p-value of fitted monotonic trend less than 0.05 (Figure 5.68). (Figure 5.69).



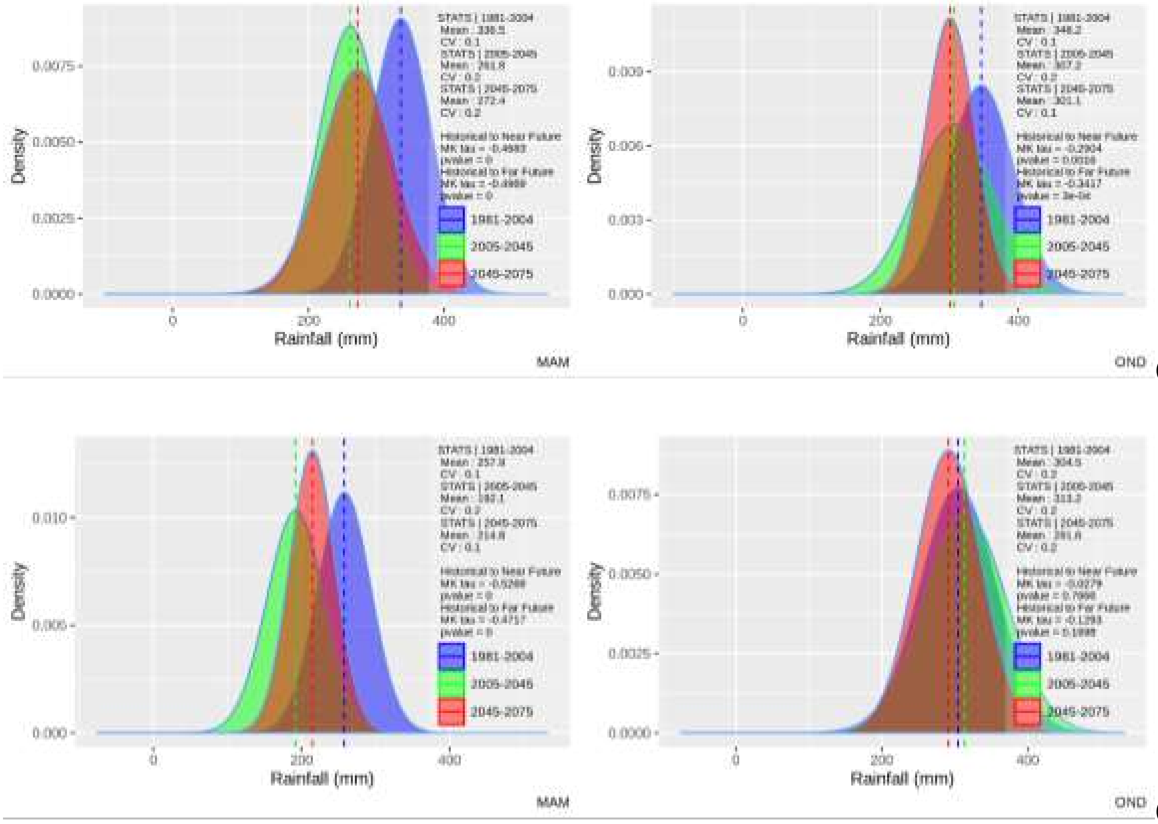
(a)



(b)

Figure 5.70 Distribution plots Showing seasonal rainfall projection over Kaptagat Forest Station for period between (1957 - 1986) and (1981 - 2075) under RCP 4.5 9 (a) and 8.5 (b) emission scenario.

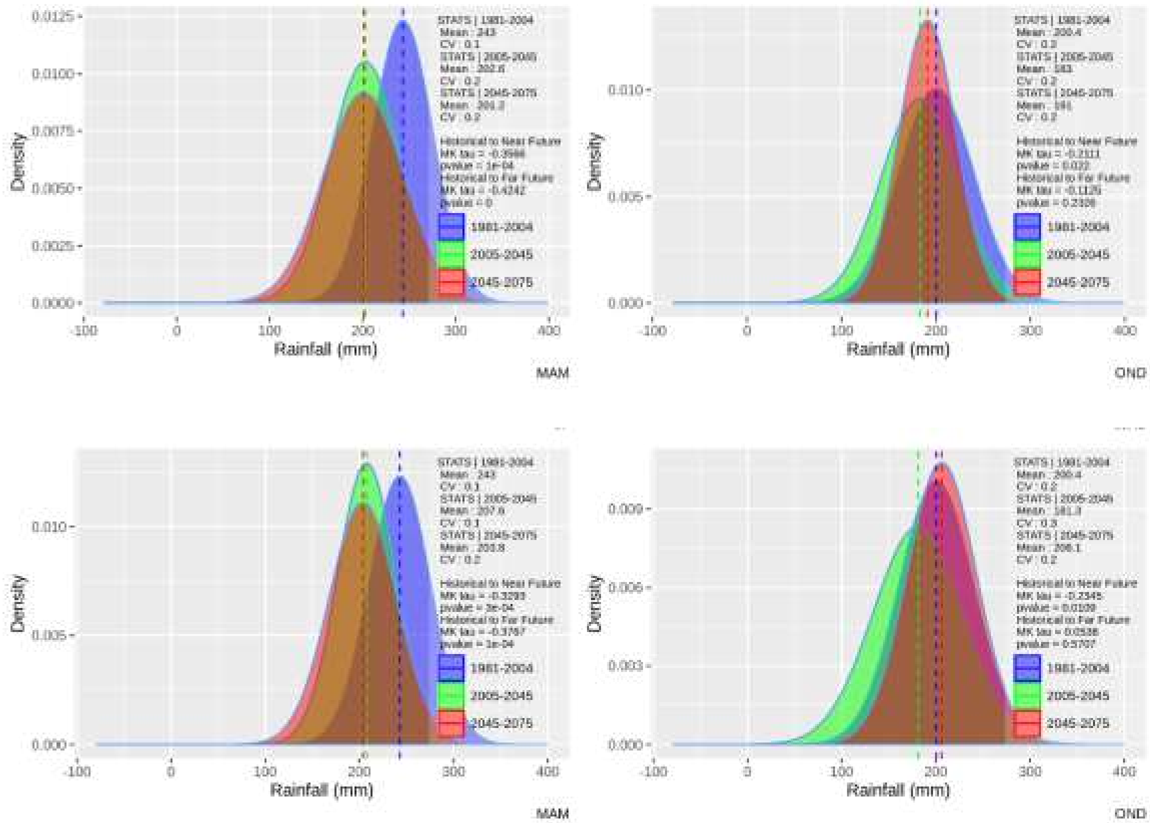
From the result of Kaptagat Forest Station, the mean rainfall for MAR-MAY rainfall is projected to decline in near future (between 2005-2045) by 64.2 mm down from 317.4 mm in historical period and further drop by and 54.2 mm in the far future (between 2045-2075). Similarly, the Oct-Dec mean rainfall is projected by the models to decrease by a magnitude of 3.8 mm down from 297.1 mm mean in the historical period for the near future and further by 8.2 mm in the far future. Suppressed rainfall is also projected by models under the RCP 8.5 emission scenario, for Mar-May mean rainfall is projected to decline by a mean of 51.7 mm in near future (between 2005-2045) and 51.9mm in far future (between 2045-2075). From the results, Oct-Dec rains are projected to decline by 9.1 mm in the near future while the far future is projected to increase by 1.7 mm. In all the emission scenarios, a declining trend for both the Mar-May and Oct-Dec rainfall was observed at Kaptagat Forest Station. From the study, the three climatological periods, those expected shifts are statistically significant at standard 95% confidence interval, as observed from p-value of fitted monotonic trend of less than 0.05 (Figure 5.70).



(a)
(b)

Figure 5.71 Distribution plots Showing seasonal rainfall projection over Kericho Meteorological Station for period between (1981 - 2075) under RCP 4.5 9 (a) and 8.5 (b) emission scenario

The result in figure 5.71, the mean rainfall for Mar-May rains is projected to decrease in the near future (between 2005-2045) by 74.7 mm and a further drop by 64.1 mm down from 336.5 mm in the far future (between 2045-2075) while, the Oct-Dec mean rainfall by the model to decrease by the magnitude of 39 mm and 4.1 mm down from 346.2 for the near future and far future respectively under the RCP 4.5 emission scenario. In the same way, under the RCP 8.5 scenario, mean rainfall for Mar-May rainfall is projected to decline by 65.8 mm in near future (between 2005-2045) and 43.1 mm in far future (between 2045-2075) while, Oct-Dec rainfall mean is projected to increase by 8.7 mm in the near future and decrease by 12.9 mm in the far future. In all the emission scenarios, a declining trend was observed for both the Mar-May and Oct-Dec rainfall. From the study, the three climatological periods, those expected shifts are statistically significant at standard 95% confidence interval, as observed from p-value of fitted monotonic trend less than 0.05 (Figure 5.71).




(a)

(b)

Figure 5.72 Distribution plots Showing seasonal rainfall projection over Kimilili Forest Station for period between (1981 - 2075) under RCP 4.5 9 (a) and 8.5 (b) emission scenario

Over Kimilili Forest Station, the mean rainfall for Mar-May rainfall is also projected to reduce in near future (between 2005-2045) by 40.4 mm down from 243 mm mean in the historical period and further by 42.8 mm in the far future (between 2045-2075) while, the Oct-Dec rainfall mean is projected to decrease by a margin of 17.4 mm and 9.4 mm down from 200.4 mm mean in the near future and far future respectively, under RCP 4.5 emission scenario. Under the RCP 8.5 emission scenario, the suppressed rainfall is projected, though with a smaller margin of 35.4 mm in the near future (between 2005-2045) and 39.2 mm in the far future (between 2045-2075) while, the Oct-Dec mean rainfall is projected to decrease by 19.1 mm in the near future and increase by 5.7 mm for the far future.  In two the emission scenarios, a declining trend was observed for both the Mar-May and Oct-Dec rainfall, with the exception of Oct-Dec rainfall which is projected to increase in the far future. From the study, the three climatological periods, those expected shifts are statistically significant at standard 95% confidence interval, as observed from p-value of fitted monotonic trend less than 0.05  (Figure 5.72).

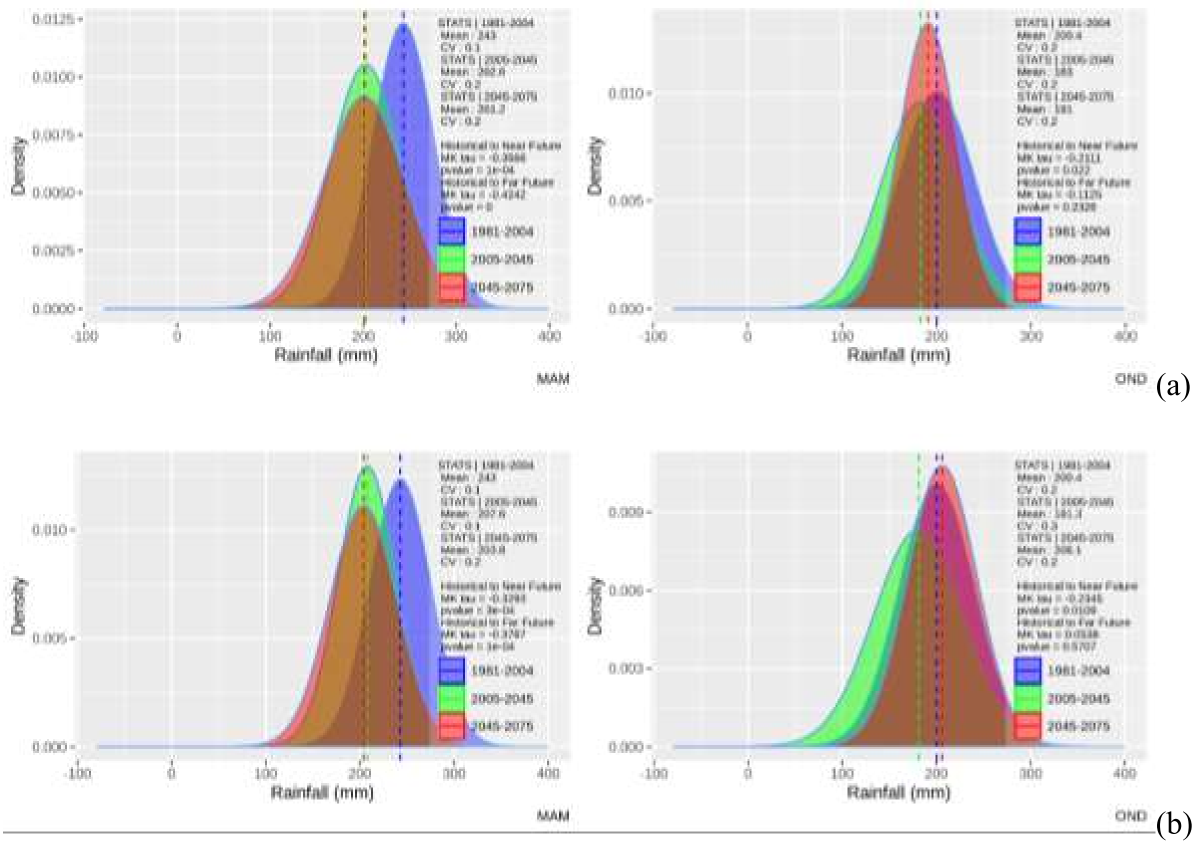
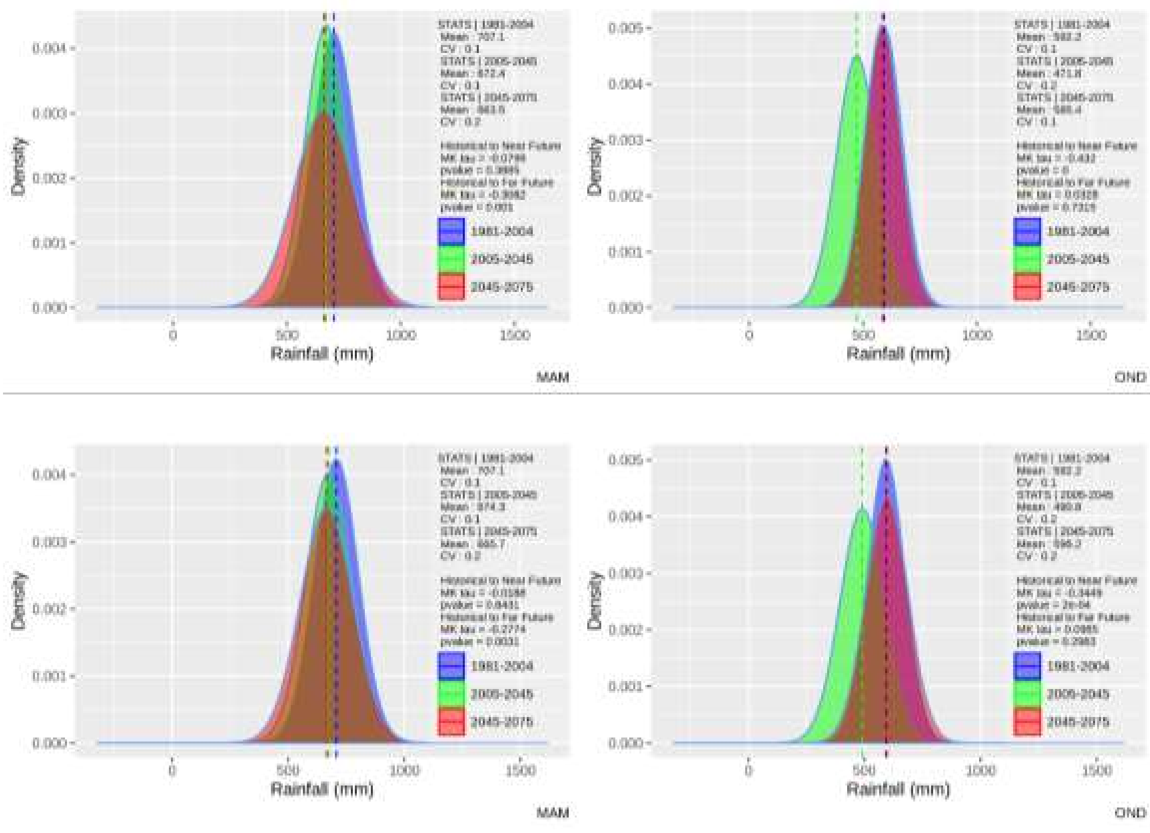



Figure 5.73 Distribution plots Showing seasonal rainfall projection over Kisii Meteorological Station for period between  (1981 - 2075) under RCP 4.5 (a) and 8.5 (b) emission scenario

The result over Kisii Meteorological Station, the mean rainfall for Mar-May rainfall is projected in near future (between 2005-2045) to decrease by 40.4 mm down from 243 mm mean in the historical period and, further drop of 41.8 mm in the far future (between 2045-2075) while; the mean rainfall for Oct-Dec rainfall is projected by the model to decrease by a margin of 17.4 mm and 9.4 mm down from 200.4 for the near future and far future respectively under RCP 4.5 emission scenario. Under the RCP 8.5 emission scenario, the mean rainfall for Mar-May rainfall is projected to decrease in near future (between 2005-2045) by 35.4 mm from and, further 39.2 mm in the far future (between 2045-2075) and, the mean for Oct-Dec rainfall is projected to decrease by 19.1 mm in the near future and an increase by 5.7 mm up from 200.4 mm in the far future. Similarly, in all the emission scenarios, a declining trend was observed both the Mar-May and Oct-Dec rainfall, with exception of Oct-Dec rainfall which is projected to increase in the far future. From the result, the three climatological periods, those expected shifts are statistically significant at standard 95% confidence interval, as observed from p-value of fitted monotonic trend less than 0.05 (Figure 5.73).

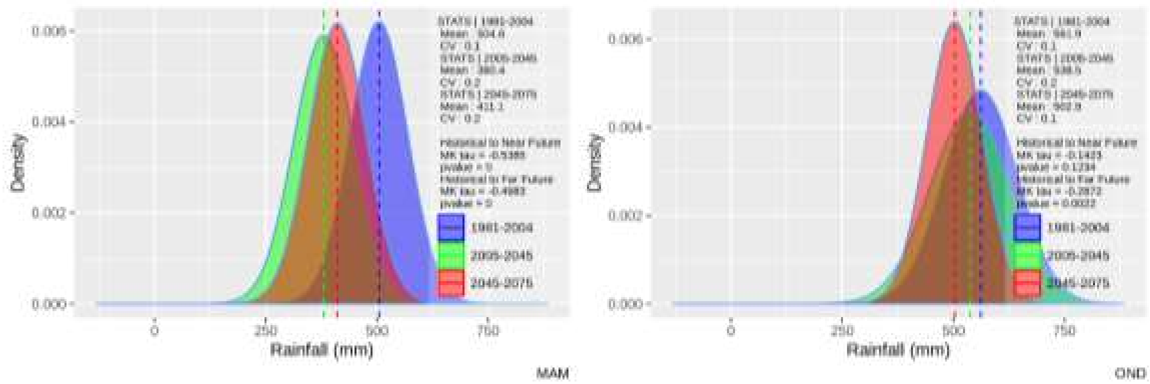



(a)

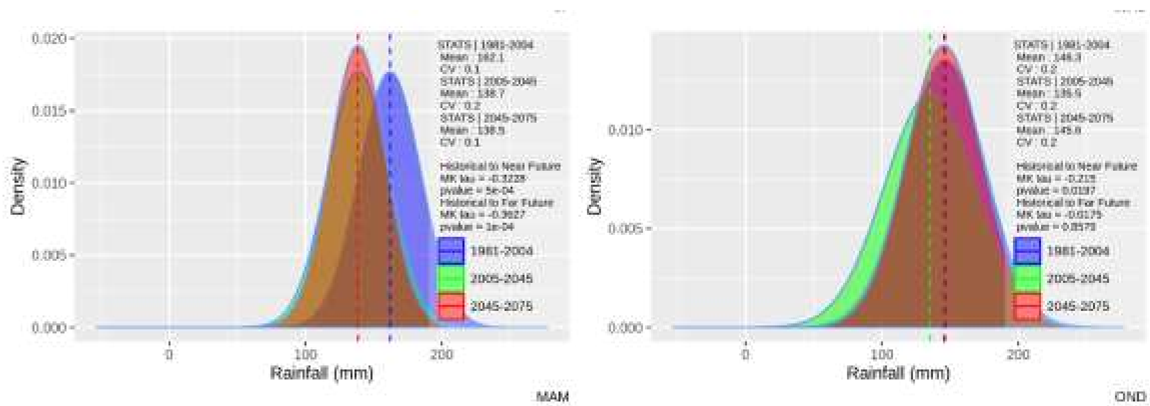
(b)

Figure 5.74 Distribution plots Showing seasonal rainfall Projection over Kisumu Meteorological Station for period between (1981 - 2075) under RCP 4.5 (a) and 8.5 (b) emission scenario

Over Kisumu Meteorological Station, the mean rainfall for Mar-May rainfall is has projected a decline in near future (between 2005-2045) by 34.7 mm down from 707.1 mm mean in the historical period and further by 43.6 mm in far future (between 2045-2075) while, a decrease in Oct-Dec rainfall mean is projected in the near future by 32.8 mm and 41.4 mm for in far future, under the RCP 4.5 emission scenario. Under the RCP 8.5 scenario, the suppressed rainfall is also projected for Mar-May mean rainfall by 120.4 mm in near future (between 2005-2045) and 6.8 mm in the far future (between 2045-2075) and, Oct-Dec rainfall mean is projected to decrease by 101.4 mm is the near future and an increase of 4 mm in the far future. In all the scenarios, a declining trend was observed for both the Mar-May and Oct-Dec rainfall, with exception of Oct-Dec mean rainfall which is projected to increase in far future. From the result, the three climatological periods, those expected shifts are statistically significant at standard 95% confidence interval, as observed from p-value of fitted monotonic trend less than 0.05 (Figure 5.74).



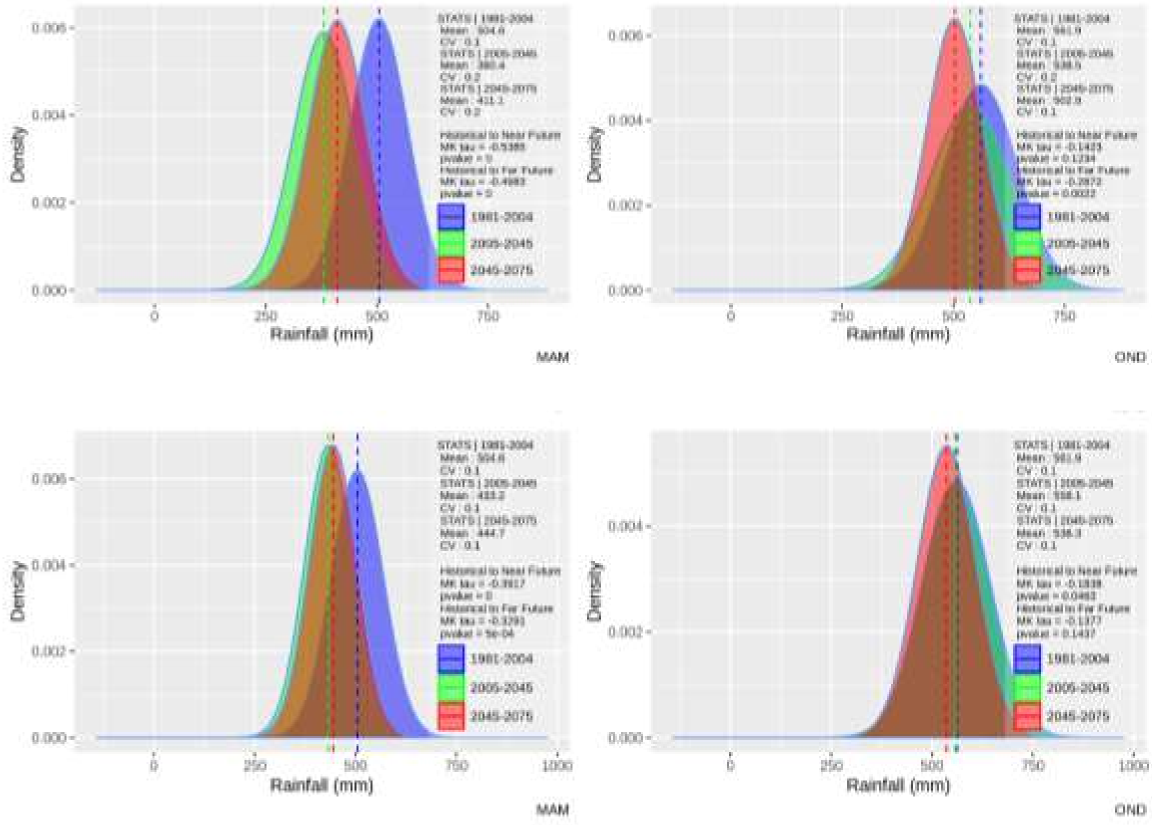
(a)



(b)

Figure 5.75 Distribution plots Showing seasonal rainfall projection over Kitale Meteorological Station for period between (1981 - 2075) under RCP 4.5 (a) and 8.5 (b) emission scenario

At Kitale Meteorological Station, the mean rainfall for Mar-May rainfall is projected a decline in near future (between 2005-2045) by a margin of 34.7 mm down from 504.6 mm mean in the historical period and further drop by 43.6 mm in the far future (between 2045-2075). Also, the Oct-Dec mean rainfall is projected to decrease by 32.8 mm and 41.4 mm down from 561.9 mm mean in the historical period for the near future and far future respectively, under the RCP 4.5 emission scenario. Correspondingly, under the RCP 8.5 emission scenario, the mean for Mar-May rainfall is projected to decline by a mean of 120.4 mm in the near future (between 2005-2045) and 6.8 mm in the far future (between 2045-2075), while, the Oct-Dec rainfall is projected to decrease by 101.4 mm in the near future and an increase of 4 mm in the far future. In all the scenarios, a declining trend was projected for both the Mar-May and Oct-Dec rainfall. From the result, the three climatological periods, those expected shifts are statistically significant at standard 95% confidence interval, as observed from p-value of fitted monotonic trend less than 0.05 (Figure 5.75).




(a) (b)

Figure 5.76 Distribution plots Showing seasonal rainfall Projection over Lugari Forest Station for period between (1981 - 2075) under RCP 4.5 (a) and 8.5 (b) emission scenario

From the above result, the mean for Mar-May rainfall is projected a decline in the near future (between 2005-2045) by 124.2 mm down from 504.6 mean in historical period and further drop by 93.5 mm in the far future (between 2045-2075) while, the Oct-Dec mean rainfall is projected by the models to decrease by 23.4 mm and 59 mm down from 661.9 mm in the near and the far future respectively, under RCP 4.5 emission scenario. Further suppressed rainfall is projected under the RCP 8.5 scenario. the mean for long (Mar-May) rainfall is projected to decease in near future (between 2005-2045) by 71.4 mm and 59.9 mm in the far future (between 2045-2075). Similarly, the mean rainfall for short (Oct-Dec) rainfall is projected to decrease by 3.8 mm and 25.6 mm in the near and the far future respectively. In all the emission scenarios, a declining trend is projected for both the Mar-May and Oct-Dec rainfall.

From the result, the three climatological periods, those expected shifts are statistically significant at standard 95% confidence interval, as observed from p-value of fitted monotonic trend less than 0.05 (Figure 5.76).

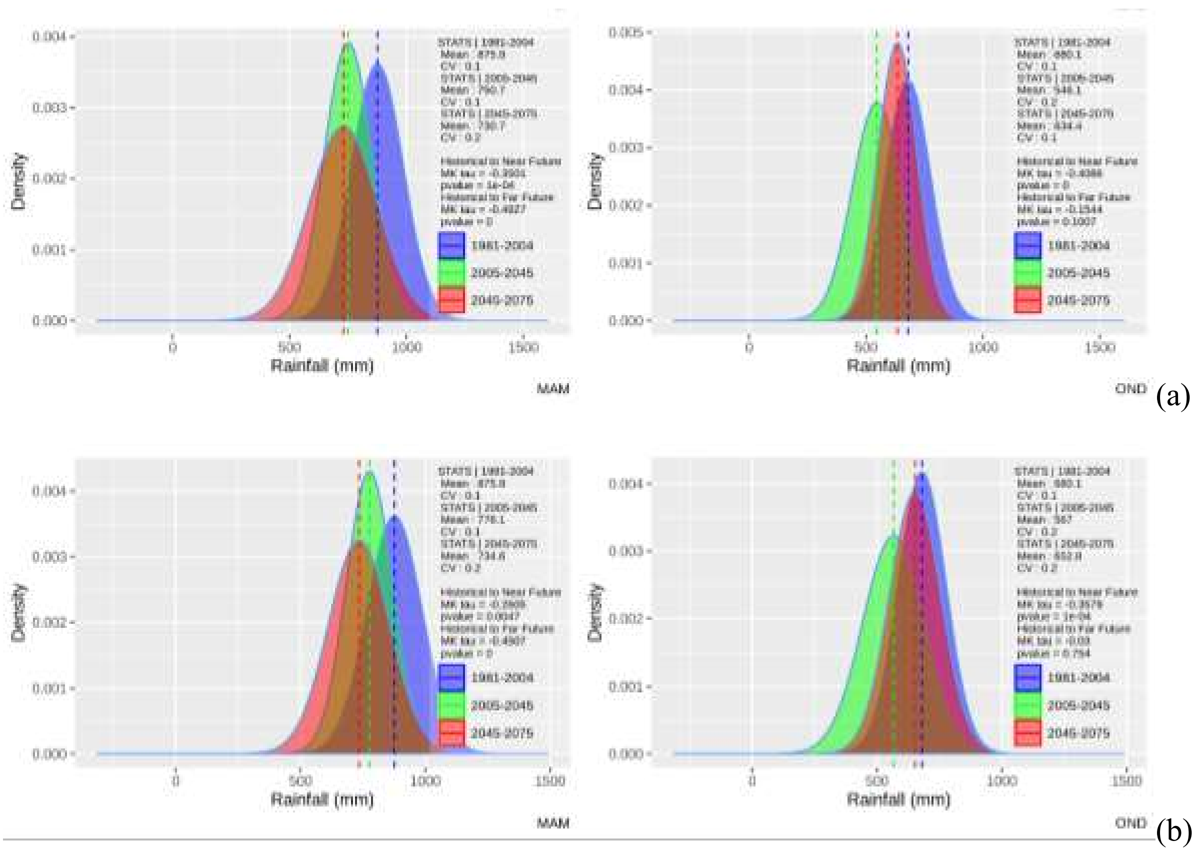



Figure 5.77 Distribution plots Showing seasonal rainfall projection over Malava Agric. Station for period between (1981 - 2075) under RCP 4.5 (a) and 8.5 (b) emission scenario

The result in figure 5.77, the mean rainfall for long (Mar-May) rains is projected a decrease in the near future (between 2005-2045) by 124.2 mm down from 875.9 mm mean in historical period and further drop by 93.5 mm in the far future (between 2045-2075) while, the Oct-Dec mean rainfall is projected to decrease in the near future by 23.4 mm down from the mean of 680.1 mm in the historical period and 59 mm and a further drop of far future, under the RCP 4.5 emission scenario. Under the RCP 8.5 emission scenario, a suppressed rainfall is projected where the mean for Mar-May rains is projected to decline in near future (between 2005-2045) by 71.4 mm and 59.9 mm in the far future (between 2045-2075) whereas, the Oct-Dec rainfall is projected to decrease by 3.8 mm and 25.6 mm in the near future and the far future respectively. In all the emission scenarios, a declining trend was observed for both the Mar-May and Oct-Dec rainfall. Following the three climatological periods results, those expected shifts are statistically significant at standard 95% confidence interval, as observed from p-value of fitted monotonic trend less than 0.05 (Figure 5.77).

The result in figure 5.78 below, the mean rainfall for Mar-May rains is projected to decrease in the near future (between 2005-2045) by 74.7 mm down from 336.5 mean in historical period and further drop by 64.1 mm in the far future (between 2045-2075) while, the Oct-Dec mean rainfall is projected to decrease the magnitude of 39.0 mm and 45.1 mm in the near and the far future respectively, under the RCP 4.5 emission scenario. Similarly, suppressed rainfall is projected under the RCP 8.5 scenario, albeit with a margin of 51.6 mm during the long rains, and 48.6 mm during short rains in the near and the far future respectively.

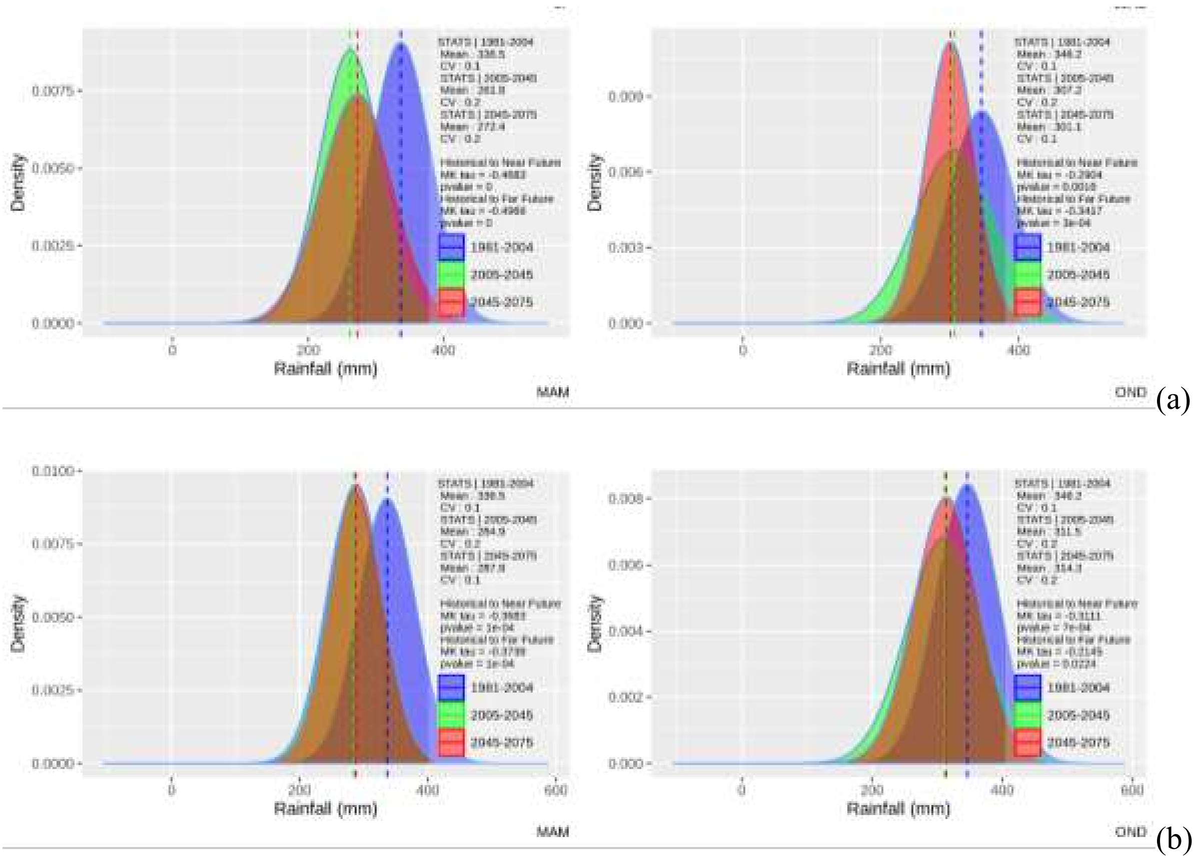



Figure 5.78 Distribution plots Showing seasonal rainfall projection over Muhuru Bay Hydromet Station for period between (1981 - 2075) under RCP 4.5 (a) and 8.5 (b) emission scenario

The OCT-DEC mean rainfall is projected to decrease futher by margin of 34.7 mm and 31.9 mm in the near and the far future respectively. In all the emission scenarios, a declining trend is projected by the models for both the Mar-May and Oct-Dec rainfall in both the near and the far future. Following the three climatological periods results, those expected shifts are statistically significant at standard 95% confidence interval, as observed from p-value of fitted monotonic trend less than 0.05 (Figure 5.78)

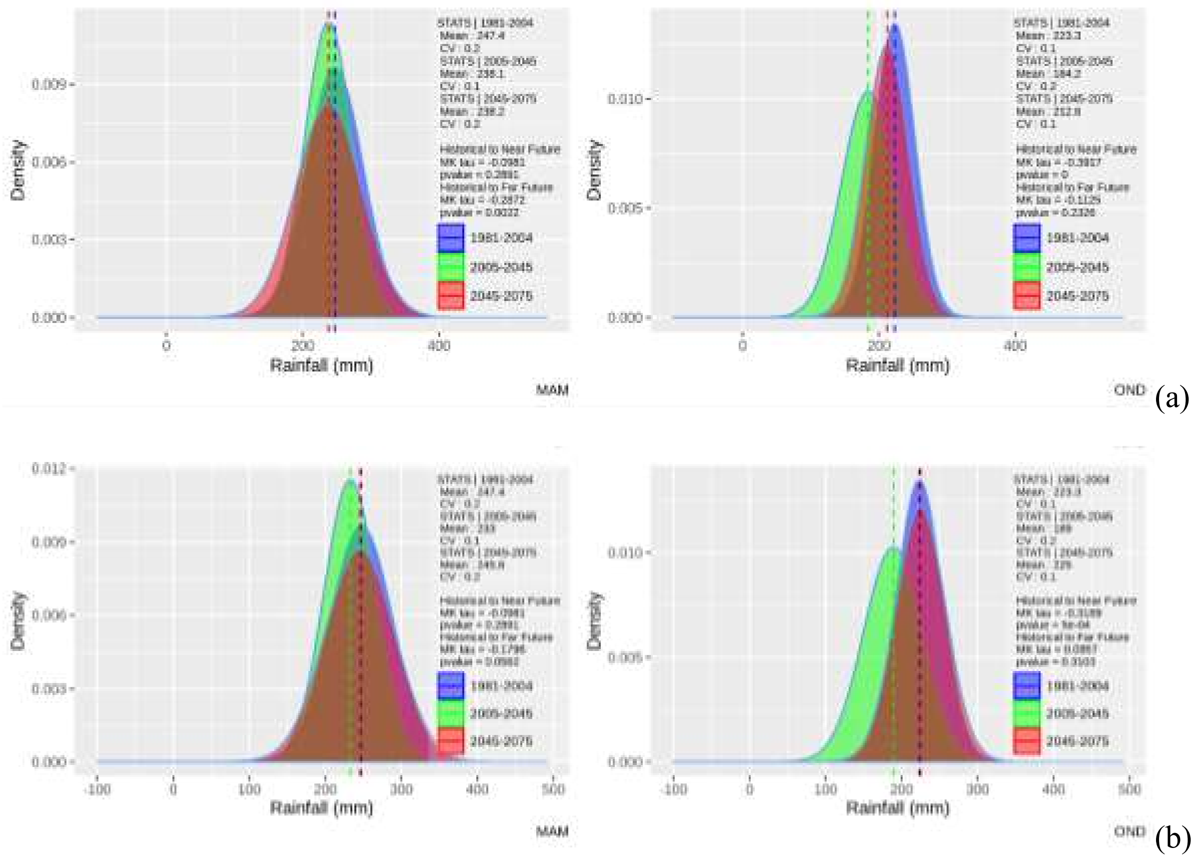



Figure 5.79 Distribution plots Showing seasonal rainfall Projection over Port Victoria Mission Station for period between (1981 - 2075) under RCP 4.5 (a) and 8.5 (b) emission scenario

The result over Port Victoria Mission Station, the mean rainfall for long rains (Mar-May) is expected to reduce in the near future (between 2005-2045) with a smaller margin of 9.3 mm and a further drop of 9.1 mm down from 247.4 mm mean in historical period in the far future (between 2045-2075) while, the Oct-Dec mean rainfall is projected to decrease in the near future by 14.4 mm and 1.8 mm and far future respectively under the RCP 4.5 emission scenario (Figure 5.79 (a). The suppressed rainfall is projected under RCP 8.5 emmision scenario, the Mar-May mean rainfall is projected by the models to decline by 14.4 mm in the near future (between 2005-2045) and 1.8 mm in the far future (between 2045-2075) whereas, the Oct-Dec rainfall is projected to decrease by 34.3 mm in the near future and increase by 1.7 mm in the far future (Figure 5.79, b).  In all the emission scenarios, a declining the trend is projected for both the Mar-May and Oct-Dec rainfall, however, the Oct-Dec mean rainfall is projected to increase with a smaller margin in the far future. From the result, the three climatological periods, those expected shifts are statistically significant at standard 95% confidence interval, as observed from p-value of fitted monotonic trend less than 0.05 (Figure 5.79).

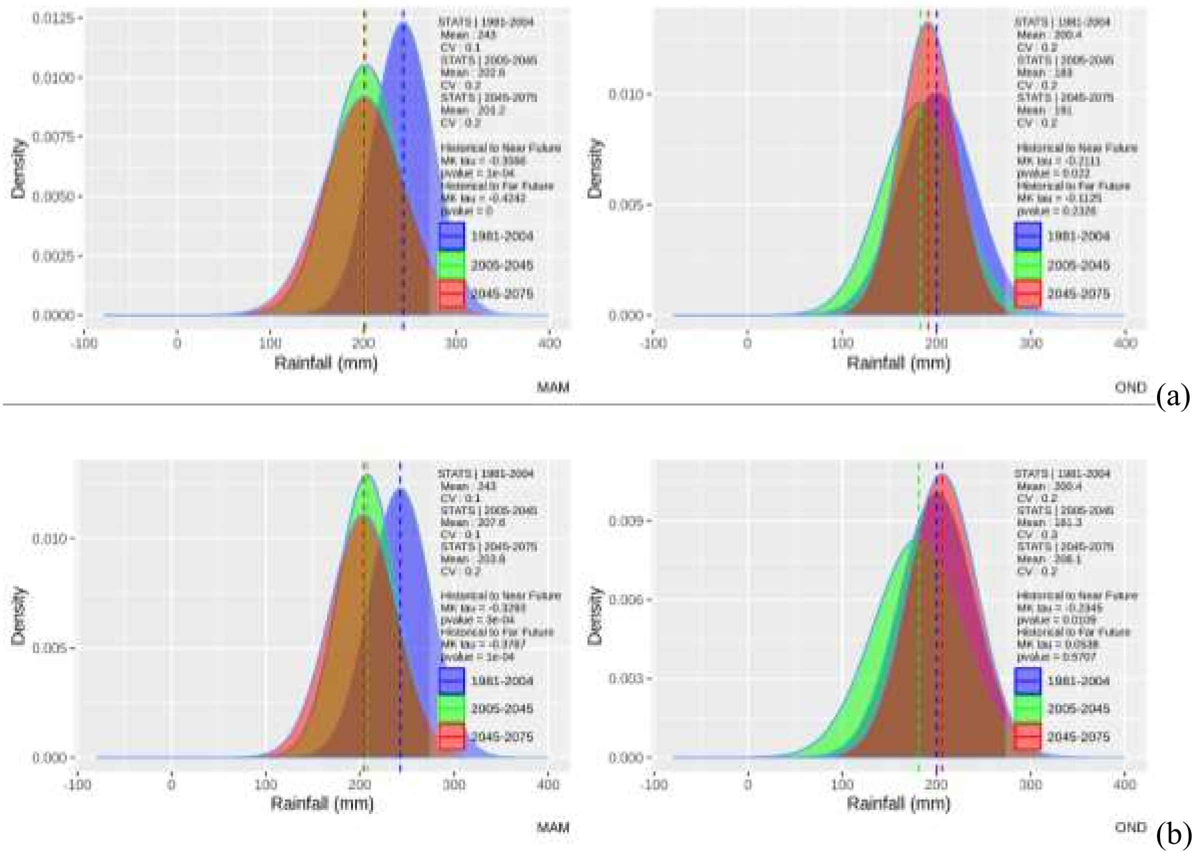
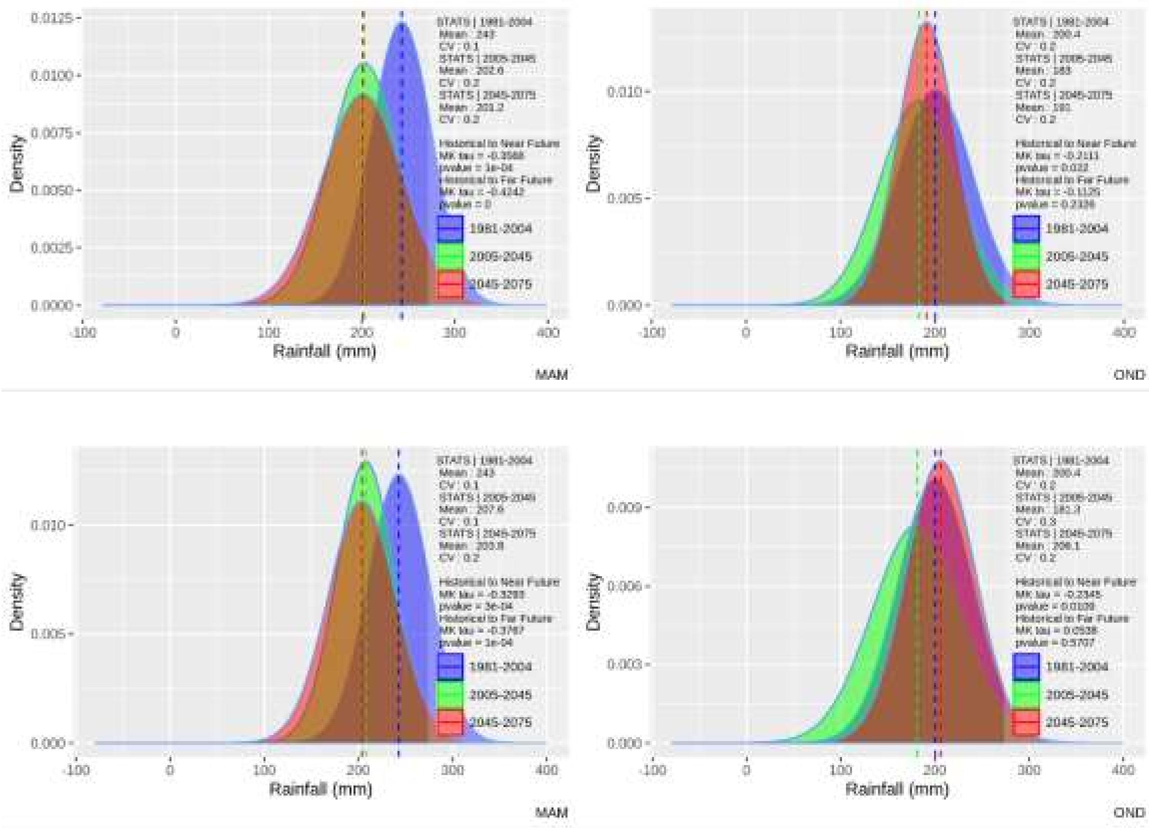



Figure 5.80 Distribution plots Showing seasonal rainfall projection over Sabatia Forest Station for period between (1981 - 2075) under RCP 4.5 (a) and 8.5 (b) scenario

The result in figure 5.80, the mean rainfall for Mar-May rains is projected to reduce in the near future (between 2005-2045) by 40.4 mm down from 243 mm mean in the historical and by 41.8 mm in far future (between 2045-2075) whereas, the Oct-Dec mean rainfall is projected to decrease a margin of 11.4 mm and 9.4 mm in the near and the far future respectively, under RCP 4.5 emission scenario (Figure 5.80 (a)). Under the same emission scenario, rainfall is projected to be suppressed in the near future (between 2005-2045) though, with a small margin of 35.4 mm for Mar-May rains and 39.2 mm in the far future (between 2045-2075) while the Oct-Dec mean rainfall is projected to decrease in the near future by 19.1 mm however, an increase of 5.7 mm is projected by the models in the far future (Figure 5.80 (a)). In all the emission scenarios, both the Mar-May and Oct-Dec mean rains are projected to decrease, however, the Oct-Dec mean rainfall is projected to increase by a smaller margin in the far future (Figure 5.80).




(a)

(b)

Figure 5.81 Distribution plots Showing seasonal rainfall projection over Sang'alo Institute Station for period between (1981 - 2075) under RCP 4.5 (a) and 8.5 (b) emission scenario

The result in figure 5.81, the mean for Mar-May mean rainfall is expected to decrease in the near future (between 2005-2045) by 40.4 mm down from 243 mm in the historical period and 41.8 mm in the far future (between 2045-2075). Whereas, the mean for Oct-Dec rainfall is expected to reduce in the near future by 11.4 mm down from the mean of 200.4 mm in the historical period and 9.4 mm in the far future, under RCP 4.5 emission scenario (Figure 5.81

(a)). Similarly, suppressed rainfall is projected under the RCP 8.5 scenario, although with smaller margins during the long rains (Mar-May) season but mixed behavior in the changes during the short rain (Oct-Dec) season. The Oct-Dec rainfall is projected to decrease in the near future by 19.1 mm and an increase of a smaller margin of 5.7 mm in the far future. In all the emission scenarios, the means for Mar-May and Oct-Dec rainfall are projected to decrease, however, the Oct-Dec rainfall mean is projected to increase a smaller margin in the far future (Figure 5.81).

### 5.5.2 Potential Climate Path for Onsets, Cessations and the Rainy Days in the Near Future

The result of the study projected variability in the onsets, cessations and the rainy days from that of the historical period between 1981 to 2005 (Figure 5.82). The onset dates of rains, their cessation dates and the number of rainy days computed for all the fourteen individual stations under two future RCP 4.5 and 8.5 emission scenarios revealed both a positive trend (shown in blue bars) and a negative trend (shown in red bars) from which it was noted that the number of rainy days was projected to decrease by about 20 days in all scenarios apart from Kisumu meteorological station and Kaptagat forest stations projected an increase of about 10 days. At Kisii Meteorological Station exhibited the higher decrease in number of rainy days by more than 50 days, under the RCP 4.5 emmission scenario. The study further projected onset dates for long rains would change deeper into the year by about 10 days in the RCP 4.5 emission scenario, while a delay of about 15 days was observed under the RCP 8.5 emission scenario. Similar changes were observed in both RCP 4.5 and the 8.5 scenario for cessation dates of long rains where a delay of about 10 days into the year was projected. The onset of short rains was also projected to occur at later dates by about 15 days in RCP 4.5 scenario and by about 5 days in RCP 8.5scenario at almost all stations, while their cessations were projected to come earlier by about 10 days under RCP 4.5 scenario and a weak change of about 5 days in RCP 8.5 scenario.

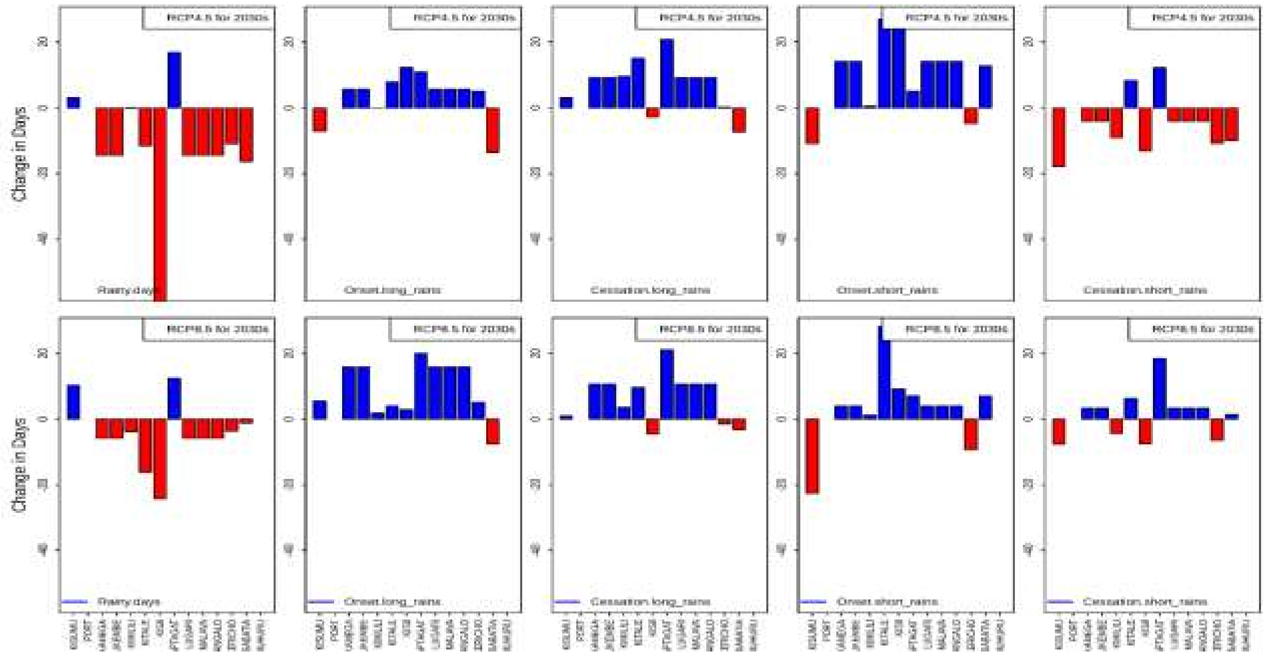


Figure 5.82: Bar plots showing the Potential Climate Pathways for rain Onsets, Cessations and the Rainy Days in Near Future (2015 to 2045).

### 5.5.2.1 Potential Climate Path for the Onsets, Cessations and the Rainy Days in Mid Future (2045 to 2075)

The characteristics of Onsets, Cessations and the Rainy Days for the historical period between 1981 to 2005 were also compared with those in the mid future (2045 to 2075) so as to investigate possible pathways. The future characteristics of the onsets, cessations and rainy days are computed under both medium mitigation of carbon emissions scenario 4.5 and under higher the uncontrolled high carbon emissions scenario 8.5. The findings were presented on side-by-side bar plots for comparison of patterns (Figure 5.83).

The study finding exhibited deviations in the projected onset dates of rains, their cessation dates and the number rainy days from the historical period between 1981 to 2005. The study revealed both positive trends (shown by blue bars) and negative trends (shown by red bars) from which the numbers of rainy days were projected to decrease by about 20 days in both scenarios. At Kisii Meteorological Station the number of rainy days were projected to decrease by more than 50 days under RCP 4.5 scenario while onset dates for long rains are projected to delay by about 20 days deeper into the year under the same RCP 4.5 scenario and by of about 10 days under RCP 8.5 scenario from what has always been historically observed. The cessation dates are projected to delay by about 10 to 20 days in RCP 4.5 scenario, while earlier cessations by about 20 days under RCP 8.5 scenario projected at most stations when compared observations in the historical period. Onset of short rains are projected to occur at earlier dates by about 5 days in most stations under RCP 4.5 scenario and about 20 days under RCP 8.5 scenario. Apart from Kisii Meteorological Station and Kitale Meteorological Station where it was projected to have later onsets of about 20 days and 5 days respectively under RCP 4.5 scenario, and a corresponding delay of about 5 days for Kitale Meteorological Station and about 15 days delays in Kisii Meteorological Station under RCP 8.5 scenario. Similar projected patterns were observed in cessation dates for short rains; earlier cessations of about 20 days for long rains in both scenarios.

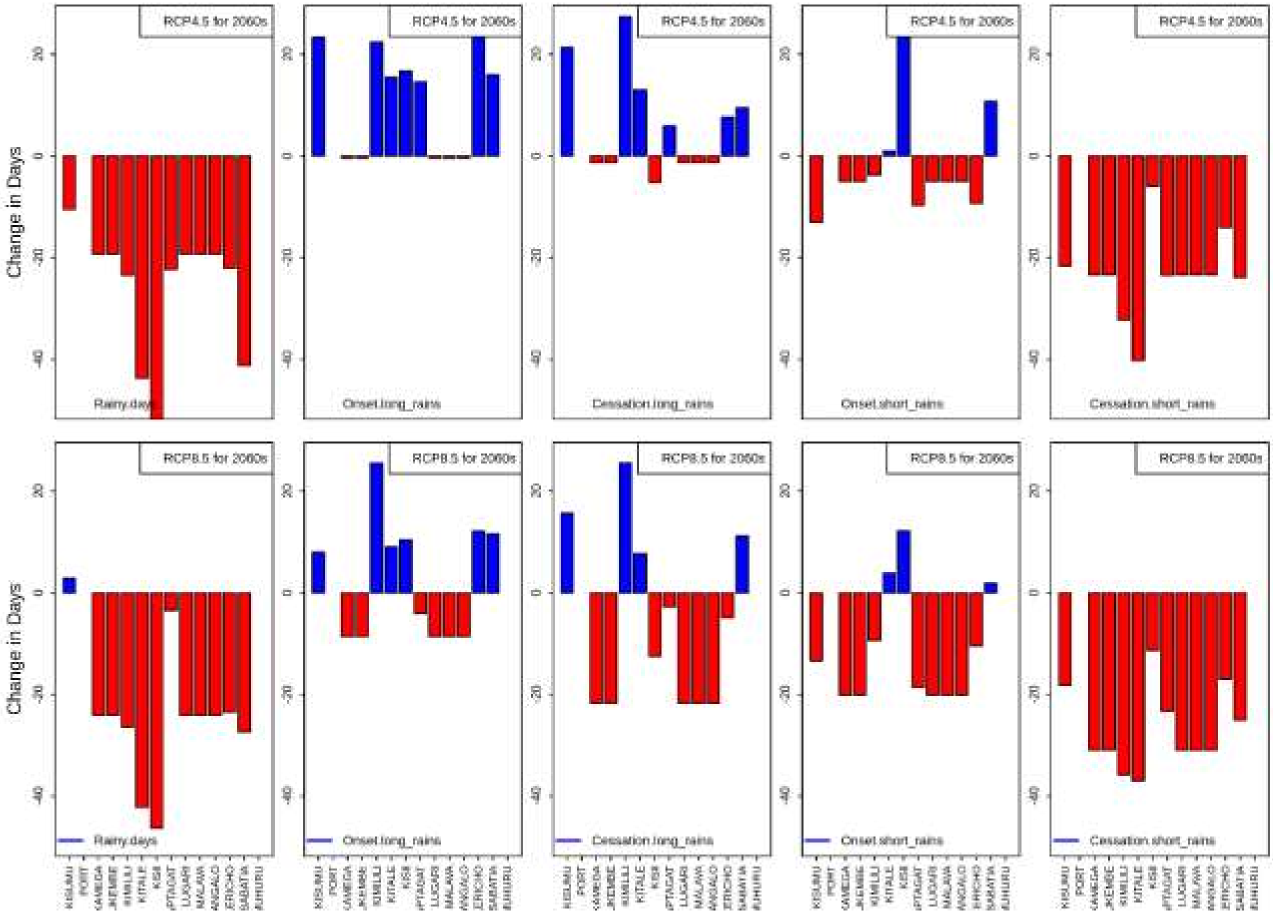



Figure 5.83: Bar plots showing the Potential Climate Pathways for rain Onsets, Cessations and the Rainy Days in Mid Future (2045 to 2075)

### 5.5.2.2 Potential Climate Path for the Onsets, Cessations and the Rainy Days in Far Future (2075 to 2105)

The characteristics of Onsets, Cessations and the Rainy Days for the historical period between 1981 to 2005 were also compared with those in the mid future (2075 to 2105) to investigate possible pathways. The future characteristics of the onsets, cessations and rainy days are computed under both medium mitigation of carbon emissions scenario 4.5 and under higher uncontrolled high carbon emissions scenario 8.5. The findings were presented on the side-by-side bar plots for comparison of patterns.

The study findings (Figure 5.83) exhibited deviations in the projected onset dates of rains, their cessation dates, and the number of rainy days from of the historical period between 1981 to 2005. The study revealed both positive trends (shown by blue bars) and negative trends (shown by red bars) from which the numbers of rainy days were projected to decrease in the five stations and, to increase in seven weather stations under RCP 4.5 emission scenarios. At Kisii Meteorological Station the number of rainy was projected to decrease by more than 50 days under both RCP 4.5 and 8.5 emission scenarios. The onset dates for long rains are projected to delay by about more than 10 days deeper in to the year for five weather stations under the RCP 4.5 emission scenario and, seven weather stations under RCP 8.5 scenario, from what has always been observed historically at the same weather station. More weather stations were projected to exhibit a delay in both onset and cessations of short rains under both scenarios.

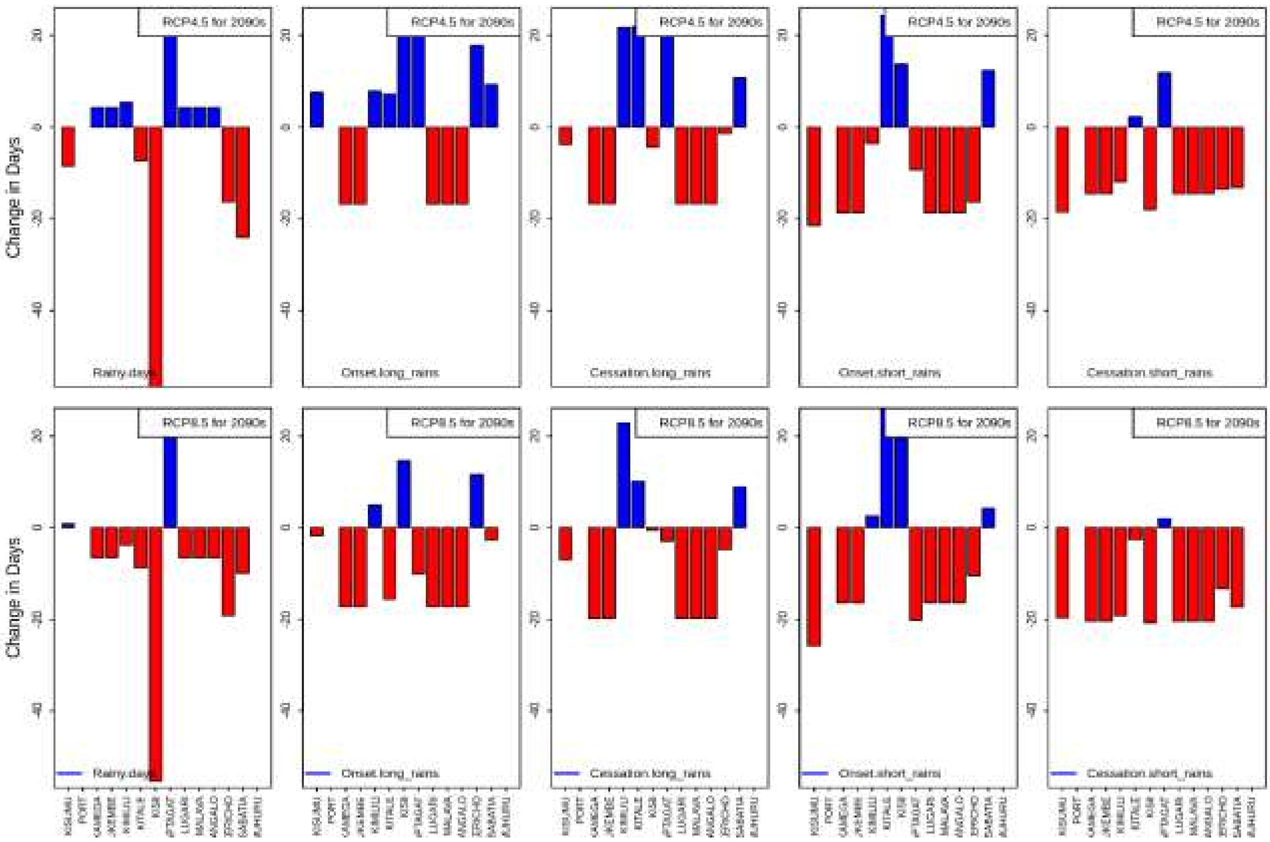



Figure 5.84: Bar plots showing the Potential Climate Pathways for rain Onsets, Cessations and the Rainy Days in Far Future (2075 to 2100s)

#### 5.5.1.3 Potential Climate Path for Temperatures over Lake Victoria Basin of Kenya

The temperature simulation under minimal pollution and high pollution have both exhibited a steady temperature increase over the LVBK (Figure 5.85). The average global temperature increases over the last decades due to increased greenhouse gases emission in the atmosphere (IPCC 2013). Over the Lake Victoria Basin, mean temperatures are projected to rise while the projection of average annual temperature is depicted to rise by 1°C to 2.4°C by 2065 with the current emission trajectory (Climate & Development Knowledge Network, 2015). The changes witnessed have recorded an increased number of warmer days and nights within the region.

whilst it is certain to project future precipitation (Sillmann et al., 2013), a good number of climate models seem to predict increased rainfall within the region (Rowell et al., 2015). The rainfall increase is linked to warming trends which increase atmospheric moisture content. According to the Climate and Development Knowledge Network (2015), the GCM projections seem to indicate that by the end of the 21st century, Eastern Africa is likely to experience wetter climates in Oct-Dec and Mar-May rainy season. The present study finding observed a downward trend for the Mar-Mar rains and subsequent increase in Oct-Dec rains. Going by the current projection, to alleviate the rural livelihood in the LVB, there is a need for proper monitoring of all climate sensitivity aspects of rural livelihood such as subsistence farming, water, and energy sources.

While there exists uncertainty in the climate projections, which is likely to further affect the preparedness of the rural livelihood. Future climate changes will have a profound effect on rural livelihoods especially agricultural productivity which determines the livelihood patterns of many households in the LVBK. The study offers an opportunity to policy-makers to understand the existing uncertainty about current and future climate which influences complex rural livelihood systems in the LVB.

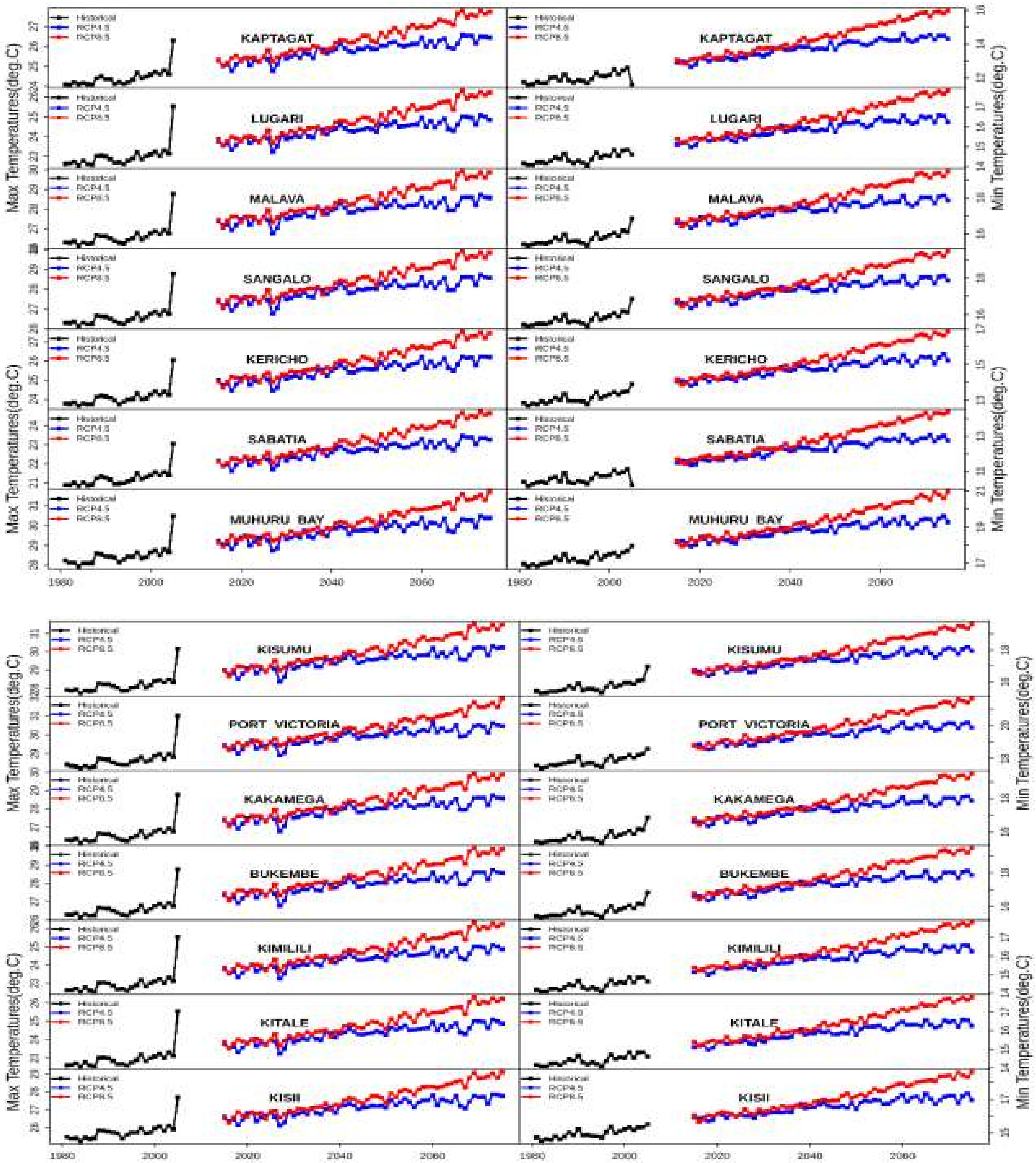



Figure 5.85: Temperature Projection under RCP 4.5 and 8.5 emission scenario for selected Stations in the Lake Victoria Basin

The Basin faces an increasing challenge on the availability and utilization of climate propelled resources due to an increase in population and the effects of changes in climates for the coming decades. Study Sangallo by Dunning et al. (2017), indicated that Africa is acute vulnerability of Africa to climate change could be associated to its population's dependence upon rain-fed agriculture as the source of their livelihoods. Luhunga et al. (2018) further predicted climate change effect on social-economic developments in developing countries. Understanding future climate change probable pathways will minimize effect of climate change on already vulnerable people. Gebrechorkos et al. (2019) recommended the use of high-resolution climate projection is for the purpose of making an informed decision in both mitigation and adaptation.

Projection of climate change, however, has been marred with a lot of uncertainty, Rowell et al. (2016) observed that such uncertain were due to a wide disparity in the magnitude of temperature and local rainfall change amongst models. This analogy is, however, disputed since more capable models are selected by an overall performance measure which does not reduce projection uncertainty. Onyitha et al. (2019) study acknowledged the use of CORDEX RCMs performed well to replicate variability in observed daily rainfall better than other GCM since it has a higher spatial resolution. Dosio (2017) projected temperature and related extreme events for Africa based on a large ensemble of CORDEX, and sound results from the study revealed a warming trend on the continent under RCP8.5 and RCP4.5, which reflects the results of this study. Stanzel et al. (2018), backed the idea of using a multi-RCM, CORDEX-Africa, since most GCMs have large uncertainty that relates to inter-model variability and the limited spatial spread of results in a single RCM used for downscaling. The Greater horn of Africa is projected to experience an accelerated warming trend than the global mean. Furthermore the length of dry spells will increase as wet seasons will decrease (Osima et al.., 2018). Dunning et al. (2018), projection on the same region revealed an increase in average rainfall per rainy day and a decline in the number of rainy days during the wet season. This study, however, revealed an increase in Oct-Dec (short) rains and a decrease in Mar-May rains as well as the number of rainy days. Gebrechorkos et al. (2019), projections similarly revealed an increase in precipitation during the short-rain season (October–December) and a decrease, up to −500 mm, in the long-rain season (Mar-My) in large parts of the region in the 2020s (2011–2040), the 2050s (2041–2070), and 2080s (2071–2100). The region was also expected to warm beyond the normal mean during the 21 centuries (Gebrechorkos et al. (2019).

In brief, the chapter presented the findings of the study and discussed the finding in view of relevant existing literature. Both the findings and discussions were presented in sub-sections guided by research objectives. The next chapter provides a summary of key findings and conclusions and recommendations drawn from the guided by key findings.

# CHAPTER SIX

# 6.0 SUMMARY OF KEY FINDINGS, CONCLUSION, AND RECOMMENDATIONS

This chapter presents the summary of key study findings, conclusion and recommendations to the policymakers and, makes suggestions on areas that need to be considered for future investigation.

## 6.1 Summary of Key Findings

The study investigated the spatial and temporal climate change and the effects it has on rural household livelihoods in the LVBK. The study was guided by the following specific objectives all relating to Lake Victoria Basin of Kenya: to assess the spatial and temporal variation in LVBK using rainfall and temperature indices, to analyze the effects of the current climate change on rural household livelihood, to establish rural household adaptation strategies and, to determine the future climate change scenarios over the LVBK.

The Lake Victoria Basin experiences two main rainy seasons: The Mar-May and Oct-Dec, long and short rains respectively. These rains significantly galvanized rural household livelihoods activities in the Lake Victoria Basin of Kenya such as subsistence farming, rearing of livestocks among others. Other rain seasons experienced in the Basin of Kenya included; Jan-Feb and June through September.

The study exposed a negative trend for Mar-May rains and, a positive trend for Oct-Dec rains from a significant number of weather stations. It was recorded that the changes seasonal rains had significantly rural livelihoods for instance, changes caused a decline in the rivers and streams flow causing water stress in some households that largely depended on surface water for domestic use. In South Eastern location, Muhuru ward, water pans could not fill up during

Mar-May rains thus gravitating water challenges during drier months.

A significant variation of at least 50% in the Mar-May rainfall onsets and cessation was noted in most weather stations, furthermore a 30% unpredictability in Oct-Dec rains cessations at Kericho, Kisumu and Sabatia was observed. The study further revealed a decline in number of rainy days caused by the variation in cessations of long rains and the onset of short rains had affected number of rainy days. This meant that onset delayed while, cessation receded early thus reducing the number of rainy days. Muhuru Hydromet station, being that is located in a drier zone of the basin, was the only weather station that was within the range of 100 to 200 Julian days; meaning that the number of rainy days had significantly remained low in the area. The study also established an increase in the mean minimum and maximum temperatures of between 0.5ºC - 0.7ºC and 0.7ºC and 1ºC respectively. However, the mean maximum temperature had significantly increased in the areas closer to Lake, while the mean minimum temperatures at the basin's highland areas.

On the investigation of the future climate scenario, the study projected a decline for both the Mar-May and Oct-Dec rains, under all the emission scenarios. A steady increase in temperature is also projected over the Lake Victoria Basin in the both the near and mind future due to the steady increase in greenhouse gases.

The finding also revealed that Climate change affected the rural household livelihoods in the Basin mainly due to frequent and prolonged severe droughts. Other effects were due increase in temperature, changes in rainfall onset and cessation, increased hailstones incidents; an outbreak of crop pests and diseases and, strong winds were the least perceived.

The climate change effects on rural household livelihoods emanated from erratic characteristic of rainfall and temperature which resulted into decline in subsistence farming and water stress. This implied more households were vulnerable due to shortages of water and agricultural supplies. The water scarcity was found more pronounced in households close to the lake literal. A decline in fish catch was also recorded to more common especially due to frequent and prolonged droughts. Few cases of human and crop diseases were also noted to have increased due to increase in the vectors. Flooding in the low land areas of the Lake Victoria Basin resulted into destruction of household property in some areas.

The revealed that most households employed various adaptation strategies to cope with the effects of climate change. These adaptation strategies included; planting drought and pest-resistant crops; diversifying agricultural activities; destocking livestock; sourcing credit facilities; constructing water storage facilities; diversifying family diet to other foods; joining CBO/self-help groups and; shifting to other livelihood activities. Further, longtime adaptation strategies were established to be essential role by the stakeholders. The long-term measures included providing farm inputs (fertilizers, seeds) to farmers; initiating irrigation; providing accurate weather forecasting; educating households on better agricultural practices (extension services), and; drilling water and constructing water pan.

## 6.2 Conclusion

Following the summary above, this study concluded that the Lake Victoria Basin of Kenya is warm and wet throughout the year, with the Mar-May and Oct-Dec rains as the two main rainy seasons. The basin has experienced a declining trend in the Mar-May rains and, an increasing trend for Oct-Dec rains, however, there was no correlation between a decrease in Mar-May and an increase in Oct-Dec rains. Furthermore, the rainfall onsets and cessations, for both Mar-May and Oct-Dec rains over Lake Victoria Basin of Kenya, have significantly varied between 1971 and 2016 resulting into reduced number of rainy days. The household observation that both Mar-May and Oct-Dec rains tended to delay, while, the cessations tended to come early, resulting food shortages was therefore justified.

The Lake Victoria Basin of Kenya has increasingly warmed between the years; 1957-2016. The mean for minimum temperature of the basin's highlands has increased by 0.6ºC-0.9ºC while the means maximum temperature has increased by 0.6ºC - 1.1º, in regions closer to Lake Victoria.

The notable climate change effects on the rural livelihoods in the LVBK emanated from frequent and prolonged severe droughts. They affected the rainfed agriculture and availability of water use at the household level. The warming of the Lake, occasioned by decline in mean rainfall has contributed to low fish catch by the fishermen. Incidents of hailstones have increased basin’s highlands, and while floods in the low land areas. These have destroyed crops in the field thus hampering household food availability and utilization. The outbreak of crop pests and diseases in the basin have been attributed to changes in basin’s climate, which has created conducive environment that harbor pest and diseases.

The annual number of rainy days are projected to decrease by about 20 days under both emission scenarios for a significant number of weather stations. For instance, Kisii Meteorological Station projected decreased rainy days by more than 50 days. However, projection of rainy days is bound to increase in some areas of the Lake Victoria Basin of Kenya especially around Kisumu meteorological station and Kaptagat forest stations where an increasing number by about 10 days was recorded.

## 6.3 Recommendations

Based on the conclusion above, the study makes recommendations to the policymakers and researchers for further study.

There is a need for policymakers to address emerging challenges of climate change at local, county and national levels, with a special focus on the rural households. Climate Change Policy within basin include creating more awareness on climate change and its effect. There is also a need for a comprehensive report and action plan on the country’s preparedness of extreme climate events at the household level.

The policy interventions through climate change action plans need to target the households on climate smart-agriculture. Such agriculture needs to incorporate the provision of pest and drought resistant crops. There is need to expand Integrated Water Use and Management projects that will help manage water stress at the household level through an effective climate change project investment policy. The project planning and management should be well be stipulated in the law.

## 6.4 Areas for further Research

There is a need for a more robust climate change study, to determine the relationship between the decrease in the Mar-May rains and the increase in the Oct-Dec rains and, their impact on annual rainfall over the LVBK. Such a study will also inform the influence those major seasonal rains have on JJAS rains that are experienced in the basin.

An attempt should be made to examine the significant variation of onset and cessation of rains, that have caused rainy days to decrease and how it affects the general ecology within the LVBK.

Furthermore, this study focused on household adaptation strategies in the LVBK, similar study is required to determine the level of climate change mitigation at the household level in the same basin.

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# Appendix I: NACOSTI Research Permit

THIS IS TO CERTIFY THAT:
MR. EVANS ODHIAMBO WABWIRE
of UNIVERSITY OF NAIROBI, 62157-200
Nairobi,has been permitted to conduct
research in Bungoma , Busia ,
Homabay , Kakamega , Kisii , Kisumu
, Migori , Nandi , Nyamira , Siaya ,
Transnzoia , Vihiga Counties

on the topic: *SPATIO-TEMPORAL CLIMATE CHANGE AND ITS ASSOCIATED EFFECTS ON HOUSEHOLD LIVELIHOODS IN THE LAKE VICTORIA BASIN OF KENYA*

for the period ending:
12th July,2018

Permit No : NACOSTI/P/17/71061/18080
Date Of Issue : 12th July,2017
Fee Recieved :Ksh 2000

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

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REPUBLIC OF KENYA

National Commission for Science, Technology and Innovation

RESEARCH CLEARANCE PERMIT

Serial No.A 14901

CONDITIONS: see back page

## Appendix II: POPULATION OF COUNTIES OF LAKE VICTORIA BASIN OF KENYA

| County | Sub County | Total | Male | Female | Area Km$^2$ | Pop density |
|---|---|---|---|---|---|---|
| Trans Nzoia | TRANS NZOIA WEST | 202,377 | 101,198 | 101,174 | 355 | 569 |
| | TRANS NZOIA EAST | 229,538 | 113,498 | 116,029 | 629 | 365 |
| | KWANZA | 203,821 | 100,234 | 103,584 | 465 | 438 |
| | ENDEBESS | 111,782 | 56,090 | 55,689 | 678 | 165 |
| | KIMININI | 242,823 | 118,087 | 124,730 | 367 | 662 |
| Kericho | BELGUT | 145,072 | 72,508 | 72,564 | 264 | 549 |
| | BURETI | 199,470 | 98,823 | 100,642 | 321 | 622 |
| | KERICHO EAST | 170,625 | 86,671 | 83,947 | 241 | 709 |
| | KIPKELION | 122,530 | 61,066 | 61,460 | 350 | 350 |
| | LONDIANI | 137,580 | 68,570 | 69,000 | 400 | 344 |
| | SOIN SIGOWET | 126,500 | 63,103 | 63,395 | 466 | 271 |
| | MAU FOREST | - | - | - | 201 | - |
| | TINDERET FOREST | - | - | - | 194 | - |
| Kakamega | BUTERE | 154,100 | 73,634 | 80,463 | 210 | 734 |
| | KAKAMEGA CENTRAL | 188,212 | 92,774 | 95,432 | 155 | 1,212 |
| | KAKAMEGA EAST | 167,641 | 80,853 | 86,784 | 417 | 402 |
| | KAKAMEGA NORTH | 238,330 | 115,511 | 122,814 | 421 | 566 |
| | KAKAMEGA SOUTH | 111,743 | 53,219 | 58,524 | 146 | 764 |
| | KHWISERO | 113,476 | 53,670 | 59,803 | 146 | 779 |
| | LIKUYANI | 152,055 | 73,710 | 78,341 | 316 | 481 |
| | LUGARI | 122,728 | 59,135 | 63,593 | 254 | 483 |
| | MATETE | 66,172 | 31,749 | 34,423 | 103 | 644 |
| | MATUNGU | 166,940 | 78,793 | 88,143 | 276 | 606 |
| | MUMIAS EAST | 116,851 | 55,895 | 60,953 | 150 | 778 |
| | MUMIAS WEST | 115,354 | 54,915 | 60,438 | 163 | 706 |
| | NAVAKHOLO | 153,977 | 73,275 | 80,695 | 259 | 594 |
| Vihiga | EMUHAYA | 97,141 | 46,507 | 50,633 | 89 | 1,091 |
| | VIHIGA | 95,292 | 45,788 | 49,501 | 90 | 1,058 |
| | SABATIA | 131,628 | 62,944 | 68,683 | 111 | 1,181 |
| | LUANDA | 106,694 | 51,525 | 55,165 | 84 | 1,265 |
| | HAMISI | 159,241 | 76,901 | 82,337 | 157 | 1,013 |
| | KAKAMEGA FOREST | 17 | 13 | 4 | 32 | 1 |
| Bungoma | BUMULA | 215,892 | 103,368 | 112,523 | 345 | 625 |
| | BUNGOMA CENTRAL | 177,748 | 86,302 | 91,438 | 233 | 764 |
| | BUNGOMA EAST | 114,548 | 55,775 | 58,771 | 163 | 702 |
| | BUNGOMA NORTH | 121,317 | 58,790 | 62,526 | 192 | 633 |
| | BUNGOMA SOUTH | 287,765 | 139,705 | 148,055 | 321 | 896 |
| | CHEPTAIS | 136,035 | 67,717 | 68,312 | 223 | 610 |
| | KIMILILI | 162,038 | 78,560 | 83,475 | 180 | 902 |
| | MT ELGON | 78,873 | 38,977 | 39,893 | 126 | 624 |
| | BUNGOMA WEST | 119,875 | 58,225 | 61,649 | 211 | 568 |

| | | | | | | |
|---|---|---|---|---|---|---|
| | TONGAREN | 100,343 | 48,685 | 51,657 | 185 | 542 |
| | WEBUYE WEST | 152,515 | 74,180 | 78,331 | 239 | 638 |
| | MT ELGON FOREST | 3,621 | 1,862 | 1,759 | 606 | 6 |
| Busia | BUNYALA | 85,977 | 41,465 | 44,511 | 192 | 447 |
| | BUSIA | 142,408 | 69,034 | 73,373 | 196 | 727 |
| | BUTULA | 140,334 | 65,136 | 75,195 | 247 | 568 |
| | NAMBALE | 111,636 | 52,900 | 58,732 | 238 | 469 |
| | SAMIA | 107,176 | 50,821 | 56,341 | 262 | 408 |
| | TESO NORTH | 138,034 | 66,412 | 71,619 | 261 | 529 |
| | TESO SOUTH | 168,116 | 80,484 | 87,630 | 303 | 555 |
| Siaya | SIAYA | 224,343 | 105,906 | 118,433 | 599 | 375 |
| | GEM | 179,792 | 85,696 | 94,092 | 405 | 444 |
| | UGENYA | 134,354 | 62,624 | 71,726 | 324 | 415 |
| | UGUNJA | 104,241 | 48,912 | 55,329 | 201 | 519 |
| | BONDO | 197,883 | 95,962 | 101,917 | 599 | 330 |
| | RARIEDA | 152,570 | 72,569 | 79,999 | 402 | 379 |
| Kisumu | KISUMU EAST | 220,997 | 108,304 | 112,689 | 142 | 1,560 |
| | KISUMU CENTRAL | 174,145 | 84,155 | 89,985 | 37 | 4,737 |
| | KISUMU WEST | 172,821 | 85,697 | 87,121 | 209 | 827 |
| | SEME | 121,667 | 57,658 | 64,007 | 268 | 454 |
| | MUHORONI | 154,116 | 76,770 | 77,345 | 658 | 234 |
| | NYANDO | 161,508 | 77,121 | 84,380 | 446 | 362 |
| | NYAKACH | 150,320 | 71,237 | 79,082 | 327 | 460 |
| Homa Bay | HOMA BAY | 117,439 | 55,756 | 61,681 | 182 | 645 |
| | NDHIWA | 218,136 | 103,706 | 114,422 | 713 | 306 |
| | RACHUONYO NORTH | 178,686 | 85,409 | 93,273 | 435 | 410 |
| | RACHUONYO EAST | 121,822 | 57,709 | 64,111 | 251 | 486 |
| | RACHUONYO SOUTH | 130,814 | 61,663 | 69,151 | 256 | 511 |
| | RANGWE | 117,732 | 55,404 | 62,325 | 274 | 429 |
| | SUBA NORTH | 124,938 | 60,530 | 64,406 | 406 | 307 |
| | SUBA SOUTH | 122,383 | 59,383 | 62,998 | 634 | 193 |
| Migori | AWENDO | 117,290 | 56,348 | 60,939 | 255 | 459 |
| | KURIA EAST | 96,872 | 46,969 | 49,894 | 188 | 516 |
| | KURIA WEST | 208,513 | 101,090 | 107,417 | 396 | 527 |
| | NYATIKE | 176,162 | 83,989 | 92,164 | 677 | 260 |
| | RONGO | 124,587 | 59,257 | 65,329 | 213 | 584 |
| | SUNA EAST | 122,674 | 58,977 | 63,694 | 205 | 598 |
| | SUNA WEST | 128,890 | 61,430 | 67,459 | 288 | 448 |
| | URIRI | 141,448 | 68,127 | 73,318 | 392 | 361 |
| Kisii | ETAGO | 83,787 | 40,137 | 43,647 | 108 | 773 |
| | GUCHA | 83,740 | 39,631 | 44,108 | 82 | 1,020 |
| | GUCHA SOUTH | 83,623 | 40,022 | 43,598 | 95 | 878 |
| | KENYENYA | 131,740 | 62,859 | 68,878 | 142 | 930 |
| | KISII CENTRAL | 166,906 | 81,330 | 85,573 | 136 | 1,229 |
| | KISII SOUTH | 135,134 | 64,514 | 70,615 | 128 | 1,054 |

| | | | | | | |
|---|---|---|---|---|---|---|
| | KITUTU CENTRAL | 154,175 | 74,608 | 79,561 | 100 | 1,537 |
| | MARANI | 107,464 | 50,598 | 56,864 | 128 | 837 |
| | MASABA SOUTH | 122,396 | 58,143 | 64,248 | 161 | 759 |
| | NYAMACHE | 130,898 | 62,113 | 68,782 | 163 | 805 |
| | SAMETA | 66,997 | 31,829 | 35,164 | 79 | 847 |
| Nyamira | BORABU | 73,167 | 36,736 | 36,431 | 247 | 296 |
| | MANGA | 94,209 | 44,868 | 49,339 | 111 | 845 |
| | MASABA NORTH | 111,860 | 52,884 | 58,974 | 142 | 789 |
| | NYAMIRA NORTH | 167,267 | 80,314 | 86,947 | 216 | 775 |
| | NYAMIRA SOUTH | 159,073 | 76,105 | 82,965 | 182 | 876 |
| TOTAL | | 13,183,540 | 6,364,106 | 6,819,113 | 25,641 | 698 |

SOURCE: Government of Kenya, 2019

**Appendix III: WMO Listed Weather Stations Targeted for a Climate study in the Lake Victoria Basin of Kenya**

| WMO station ID. | Weather Station Name |
|---|---|
| 88.34.001 | North Mount Elgon Forest station |
| 90.34.032 | Moromba Farmers Cooperative society |
| 90.34.065 | Nyamira District Office |
| 91.43.019 | Ntimaru Chief's Office |
| 89.34.072 | Kaimosi Tea Estate Ltd |
| 90.34.001 | Kisii District Commissioner Office |
| 90.34.046 | Nyabomite Farmers Co-operative |
| 89.43.078 | Kaimosi Farmers Training Centre |
| 90.34.031 | Nyaturubo F. C. Society |
| 89.34. 028 | Kakamega Forest Station |
| 89.34.060 | Kimilili Agricultural Department station |
| 89.34.016 | Lugari Forest Station |
| 89.34.061 | Malava Agricultural Station |
| 89.34. 103 | Tambua Agricultural Station |
| 89.34.001 | Kakamega DC's Office |
| 90.34.048 | Rapogi Secondary School |
| 90.34.069 | Kibos Kisumu Water Supply |
| 90.34.005 | Kamagambo School |
| 90.34.056 | Nyakoe F. C. Society |
| 90.34.047 | Uriri Chief's camp |
| 89.34.002 | Bukura Farmers Training College |
| 89.34.031 | Yala St. Mary's School |
| 90.34.023 | Oyugis Agricultural Office |
| 90. 34.011 | Maseno Veterinary Office |
| 89.34.082 | Kibingei Agricultural Department |
| 90.34.041 | Marinde Dispensary |
| 90.34.045 | Kosela Primary School |
| 90.34.062 | Kodera Forest Station |
| 90.34.066 | Magunga Chief's camp |
| 90.34.010 | Lower Midland Zone Agricultural Office |
| 91.34.015 | Kihancha Agricultural office |
| 69.33.026 | Port Victoria Catholic Mission |
| 89.34.030 | Nangina Catholic Mission |
| 89.34.037 | Lukolis Dispensary |
| 89.34.039 | Butula Catholic Mission |
| 89.34.058 | Sega Primary School |
| 89. 34.059 | Uholo Chief's Camp |
| 90.34.004 | Kisumu PC's Office |
| 90.34.007 | Miwani Sugar Secondary |
| 90.34.018 | Gendia Chief's Camp |
| 90.34.021 | Bondo Usigu Health Centre |
| 90.34.025 | Kisumu Met. Station |

| | |
|---|---|
| 90.34.060 | Kisumu New Prison |
| 90.34.063 | Lambwe Divisional Office |
| 90.34.081 | Kibos Cotton Exp. Station |
| 90.34.046 | Chemelil Plantation |
| 91.34.009 | Lower Midland Zone Bay Hydromet Station |

## Appendix IV: Household Questionnaire

| | | | |
|---|---|---|---|
| Questionnaire no. | | Date of interview: | _ _ / _ _ / _ _ |
| Name of Ward/ Sub -Ward | | Name of Ward: | |
| | | Location: | |
| Name of field Assistant | | Date of data entry: | _ _ / _ _ / _ _ |

I am Evans Odhiambo Wabwire, a Ph.D. student at University of Nairobi (Reg. No. C80/ 50967/2016) pursuing a Doctor of Philosophy in Climatology. In line with academic requirements, I am carrying out research on SPATIO-TEMPORAL CLIMATE CHANGE AND ITS EFFECTS ON HOUSEHOLD LIVELIHOOD IN THE LAKE VICTORIA BASIN OF KENYA.

This questionnaire is formulated for the purpose of acquiring relevant information to addressed research questions. Be assured that your identity and information will be treated with a lot of confidentiality. The information received from you is only for the academic purpose and shall not be used for any other purpose.

**Section A: Respondent, household, livelihood and vulnerability**

A.1 Respondent and household information

1. Gender: Male ( ) Female ( )
2. Age Bracket: Under 20 ( ) 21-30 ( ) 31-40 ( ) 41-50 ( ) Over 50 ( )
3. Matrimonial status: Single ( ) Monogamous marriage ( ) Polygamous marriage ( ) Widowed ( ) Separated/divorced ( ) Other ( ), specify __________
4. Place of birth: This sub Ward ( ) Elsewhere ( ) specify region _________________
5. Education level: None ( ) Primary ( ) Secondary ( ) Tertiary ( ) Technical/vocational ( ) Other ( ), specify_______________
6. Occupation activities: Farming ( ) Livestock raising ( ) Fishing ( ) Trading ( ) Salary work ( ) Other ( ) specify ________

**A.2 Household Land Resources**

1. Does your household own land? Yes ( ) No ( )
   a) Explain the use of the land
   ----------------------------------------------------------------------------------------------------
2. Do you (or does your household) engage in farming? 1. Yes ( ) 2No ( ) (if no, go to next section)
3. Do you do farming under irrigation? 1.Yes( ) 2.No ( )
   a) If yes, how much? Number _____ Unit ________
4. Identify the crop you plant in your farm, in order of preference
   ----------------------------------------------------------------------------------------------------
   ----------------------------------------------------------------------------------------------------
5. The use of crops produces in your farm

--------------------------------------------------------------------------------------------------------7.

If you sell, identify the quantities for sell?

7. ----------------------------------------------------------------------------------------------------

What would you say to your crop production in the last 10 years

1. Decrease ( ) 2.. Remain the same ( ) 4. Increase ( ) 5. Not sure ( )

b) If your crop production has changed, state the causes

______________________________________________________________________________

**A.3 Other Household Livelihood Activities**

1. Do you own domestic animals? . Yes (   ) 2. No (   )
   a) If yes, check the one you own
   ------------------------------------------------------------------------------------------------
   b) The main purpose for your livestock
   Household consumption (   ) Sale (   ) Traction (   ) Other(   ) specify ______
2. Does any member of your household engage in fishing activities? Yes (  ) No (   )
   a) Identify the purpose of your fishing activities

------------------------------------------------------------------------------------------------

A.4 Household Non-Farm Livelihood Activities

1. Does any member of your household engage in non-farm activities as source of livelihoods? Yes (   ) No (   )

a) Indicate the non farm activities engaged in for livelihoods (multiple options)?

______________________________________________________________________________

______________________________________________________________________

1. If you compared your households income to others, would you say it is (1) Less most others (   ) (2) Average(   ) (3) More than others (   )

**A.5 Household Housing Assets**

1. Do you 'own' the house (s) you live in? 1. Yes (   ) 2.No (   )
2. The building materials for the housing ( make observation):
   a) Roof -------------------------------------------------------------------------------------------
   b) Walls ----------------------------------------------------------------------------------------
   c) Floor -----------------------------------------------------------------------------------------
3. What is your source of energy? Electricity (   ) Solar (   ) Kerosene(   )
   Others (   ) Specify _____________
4. Identify the source of water for domestic use ?

   ______________________________________________________________________

**A.6 Household Food security**

1. How many meals does your household have in a day ________
2. Were there times that you had less 1. Yes (   ) 2. No (   )
   a. If yes, identify the months of occurrence
   ------------------------------------------------------------------------------------------
   Identify the causes of your household food shortages
3. Do you buy foofd for household consumption 1. Yes (   ) 2. No (   )

**Section B**

**2. Adaptation Strategies**

A 1. How many years have you lived in this location? _______

B. 1. State the climate event that affect your household livelihood activities ____________

2. How did the climate event above affect your livelihood activities?

4. Did your household any climate adaptation strategy ? Yes (   ). No (   )
   a) i) If yes, identify the climate strategy ?-
   ________________________________________
   iii) If yes. Measures were not enough (   ) measures have costs (   ) other reason (   )
   Please explain________________________________
   b) i) If no, explain why
   _____________________________________________________

**B.2 Effect of Climate change on Household Livelihoods**

2.1. How would you classify the effect of climate change on your household
1. No effect (  ) 2. Yes, but not severely (  ) 3. Yes, severely (  )

2.2. If yes explain,

a) Livestock-----------------------------------------------------------------------------------------
b) Fishing ------------------------------------------------------------------------------------------:
c) Economic trees--------------------------------------------------------------------------------
d) Trade---------------------------------------------------------------------------------------
e) Food prices--------------------------------------------------------------------------------------
f) Properties damage---------------------------------------------------------------------------
g) Others -----------------------------------------------------------------------------------

2.3

4. Did you receive any support from an organization to deal with this Extreme climate event (multiple options)? 1. No (  ) 2. Yes (  )

i) If yes explain, ---------------------------------------------------------------------------

5. Did your household to earn extra income to deal with this extreme climate events (multiple options)? 1. No (  ) 2. Yes (  )

a) If yes explain, ---------------------------------------------------------------------------------

b) were there any migration among your family members due to climate event?

1. No (  ) 2. Yes, (  )

b) Did your household sell properties to deal with this extreme climate event?

1. No (  ) 2. Yes, 1

If yes explain ------------------------------------------------------------------------------

c) How did you cope with food situation in your household ---------------------------------------------------------------------------------------------

**Section C**

3.1 What kind of changes in climate have you noticed in this area for the past years your residence in this location?

___________________________________________________________________________

1) Identify measures your household has taken to adapt to the following area
h) Farming activities

___________________________________________________________________________

ii) Livestock keeping

___________________________________________________________________________

iii) Non-farm activities

___________________________________________________________________________

iv) Water availability

___________________________________________________________________________

v) Food security/ Nutrition

___________________________________________________________________________

vi) Household properties

___________________________________________________________________________

End

Thank you for your time.

## Appendix V: Key Informants Questionnaire

| | | | |
|---|---|---|---|
| Questionnaire no.: | _______________ | Date of interview: | _ _ / _ _ / _ _ |
| Name of Ward/ Sub -Ward | | Name of Ward: | _______________ |
| Date of data entry: | _ _ / _ _ / _ _ | Name of data entry officer: | _______________ |

I am Evans Odhiambo Wabwire, a PhD student at University of Nairobi (Reg. No. C80/ 50967/2016) pursuing a Doctor of Philosophy in Climatology. In line with academic requirements, I am carrying out a research on SPATIO-TEMPORAL CLIMATE CHANGE AND ITS ASSOCIATED EFFECTS ON HOUSEHOLD LIVELIHOOD IN THE LAKE VICTORIA BASIN OF KENYA.

This interview guide is formulated for the purpose of acquiring relevant information to addressed research questions. Be assured that your identity and information will be treated with a lot of confidentiality. The information received from you is only for the academic purpose and shall not be used for any other purpose.

Section A: Respondent, household, livelihood and vulnerability

**A. 1 Respondent and household information**

1. Gender: 1. Male ( ) 2. Female ( )
2. Age Bracket: 1. Under 20 () 2. 21-25 () 3. 26-30 ( ) 4. 31-35 ( )5. Over 36 ( )
3. Place of birth: ------------------------------------------------------------------------------------------
4. Level of Education ------------------------------------------------------------------------------------
5. Occupation: 1. Salary work ( ) 2. Farmer ( ) 4. Business ( ) 6. Other ( ) specify ________

A.2 Land and farm

a) For what purpose do people use land in this Ward (multiple options)?

-----------------------------------------------------------------------------------------------

b) i) Is there some land in this sub Ward that is under irrigation? 1. Yes( ) 2.No ( )
   ii) If yes, what is the reason for irrigating the land

c.) Which crops do households cultivate in their farms? [in order of importance]
   (1) _________________ (2) __________________ (3) ________________
   (4) _________________ (5) _________________ (6) _________________

d) i) In the last 10 years, did crop production in this sub Ward
   ----------------------------------------------------------------------------------------------
   ________________________________________________________________

A.3 Livestock, fishing and economic trees

a) i) Do households in this ward own livestock? Please indicate [in order of preference]
   ----------------------------------------------------------------------------------------------
   ________________________________________________________________

   ii) Identify factors that affect the productivity of the above
   ________________________________________________________________

b) i) Do household members in this sub Ward engage in fishing or fish raising/business?
   1. Yes ( ) | 2. No ( )
   ii) Explain how climate affect the above activities
   ________________________________________________________________

A.4 other income generating activities

a) Identify any non-farm activities that household members derive their income from?
______________________________________________________________________

b) In the order above, explain how the they are affected by climate events
______________________________________________________________________

A.5 Housing and other assets
a) In what ways have climate events affected the following in this Ward?
i) Housing ____________________________________________________________
ii) House of power______________________________________________________
iii) Sources of drinking water ______________________________________________
iv) Sanitary facilities___________________________________________________

A.6 Food security
a) i) Do the residents of this ward have stable food supply Yes ( ) 2. No ( )
ii) If No, what is the cause of food shortage?
______________________________________________________________________

b) In the past ten years, what has been the frequency any food shortages?
______________________________________________________________________

Section B

2. Climate Change impact and coping Strategies
a) i) which climate events affect this Ward (mention the most severe one or the most recent one)
______________________________________________________________________

ii) Please mention the years and the climate event (you can remember)

| Year | Climate event |
|---|---|
| | |
| | |

b) In what ways did the above climate events affect the household livelihoods in this Ward?
______________________________________________________________________

c) i) Was there any support given to the residents of this Ward? 1. Yes ( ) 2. No ( )
ii) If yes, specify the nature and source of support
______________________________________________________________________

4. Vulnerability, gender and policy
a) Do you think that residents this location are more or less likely to suffer from the impacts of climate events than other Wards in the Lake Victoria Basin?
1. More ( ) 2. Average ( ) 3 Less ( ) Why? ________________________

b) Is there gendered vulnerable to climate change
1. Male ( ) 2. Female ( )
c) Explain how they are vulnerable
______________________________________________________________________

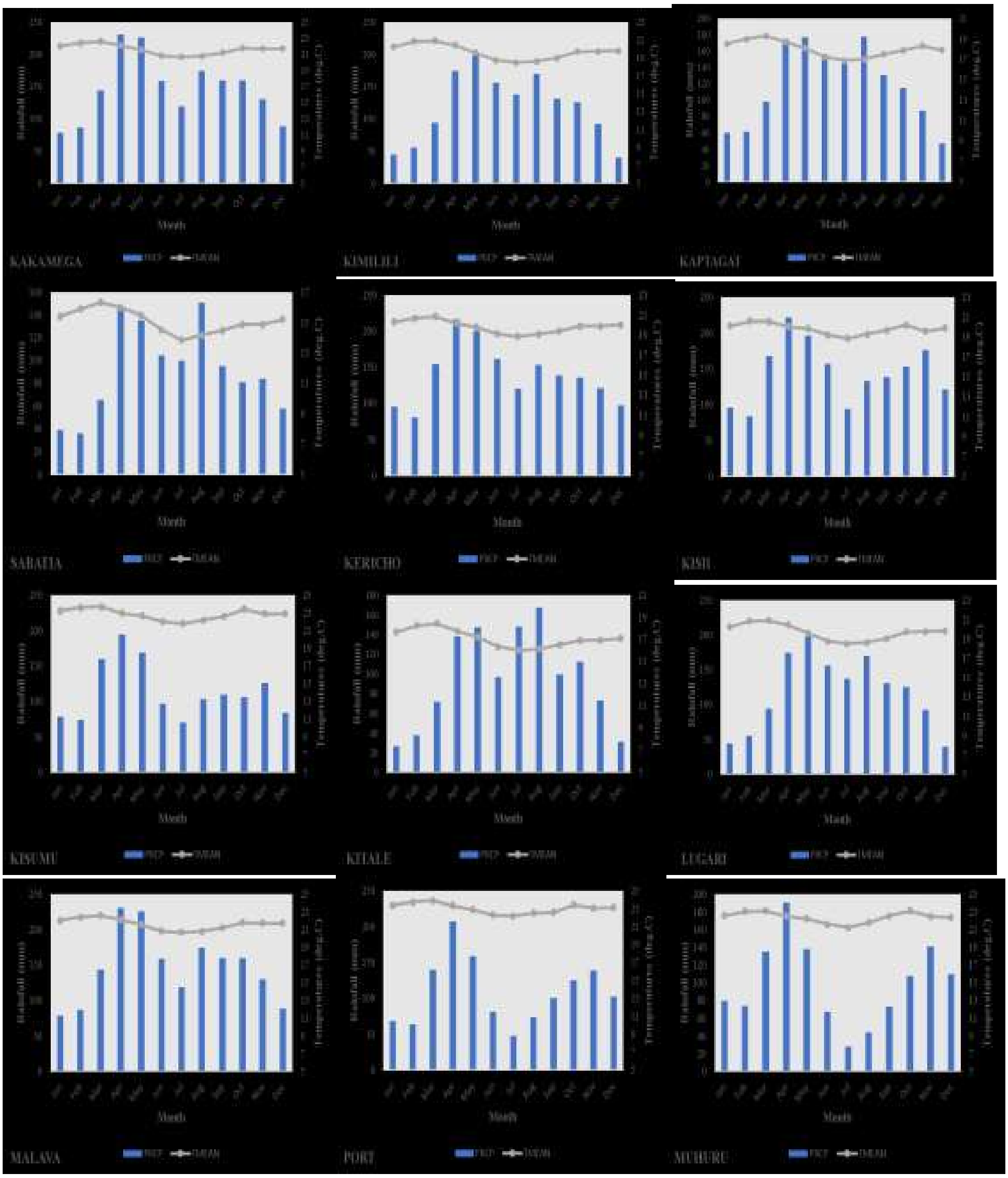
d) i) Are gender roles affected by extreme climate events?
1. No ( ) 2. Yes ( )
ii) Please explain
______________________________________________________________________

c) What roles should the government or other NGOs do to lessen climate change effects?
______________________________________________________________________

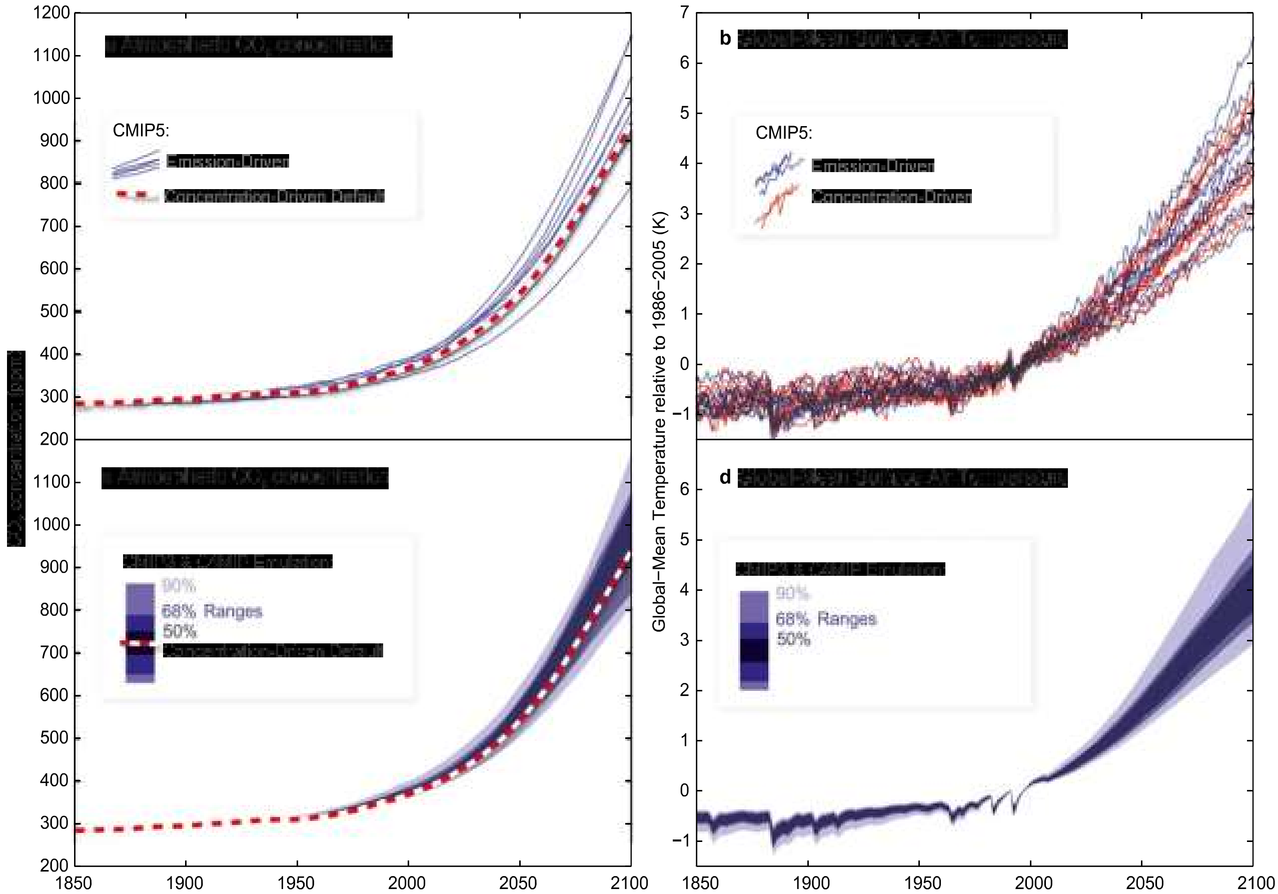
End

Thank you for your time.

**Appendix VII: Appendix VII: The Mean Monthly Climatology for Rainfall and temperatures for all Selected Weather Stations in the Lake Victoria Basin of Kenya**



**Appendix VI: Simulated Atmospheric Co2 Concentration (Ppm) Versus Global Surface Air temperature**




Source : journals.ametsoc.org