UNIVERSITY OF NAIROBI

ASSESSMENT OF SMALL-SCALE FARMERS PERCEPTION AND ADAPTATION TO CLIMATE CHANGE IN NYATIKE SUB-COUNTY

BY

ERICA ATIENO ONYANGO

I54/7705/2017

A DISSERTATIAON SUBMITTED IN PARTIAL FULFILMENT OF MASTER OF SCIECNCE DEGREE IN CLIMATE CHANGE OF THE UNIVERSITY OF NAIROBI

JUNE, 2021

DECLARATION

I hereby declare that this dissertation is my original work and has not been presented and submitted in any other University.

Erica Atieno	E.A.	18/06/2021
154/7705/2017	Signed	Date
Department of Meteorology		
University of Nairobi		

This dissertation has been submitted for examination with our approval as university supervisors:

Dr. Christopher Oludhe		18/06/2021
Department of Meteorology	Signed	Date
University of Nairobi		

Dr. Fredrick Karanja		
Department of Meteorology	Signed	Date
University of Nairobi		

ACKNOWLEDGEMENTS

I would like to express my sincere gratitude to my supervisors, Dr. Christopher Oludhe and Dr. Fredrick Karanja for their continuous support and guidance during the entire period of my research. I would also like to thank the staff at Nyatike subcounty Ministry of Agriculture and Livestock for their support throughout the data collection exercise in the field.

ABSTRACT

Agriculture is the most dominant source of livelihood for rural households in developing countries. However, agricultural production is climate sensitive especially in areas that rely on rain-fed agriculture, including in sub-Saharan countries such as Kenya. More specifically, semi-arid areas such as Nyatike subcounty in Kenya have been found to elicit vulnerability to climate change by a dearth of studies yet, to my knowledge, no study has delved into the information base of the small-scale farmers in the area on climatic changes and the climate change adaptation strategies they embrace. To contribute to addressing the identified gap, this study sought to quantitatively assess the rainfall and temperature patterns in Nyatike subcounty, perception of climate change, and climate change adaptation strategy uptake among small-scale farmers in the sub-County.

Understanding the aforementioned issues is vital in proposing measures that will increase resilience of small-scale farmers to adapt to the changes in climatic conditions within the region. This study used primary and secondary data. Primary data collection involved administering a semi-structured questionnaire to 150 farmers to determine their perception on climate change and how they are adapting. The study also used secondary data from the TerraClimate database to examine the rainfall and temperature patterns over two climatological periods 1961-1989 and 1990-2018. Perception and adaptation to climate change were analysed using probit and logit econometric models respectively. Regression analysis of the timeseries data revealed that the mean annual rainfall has been decreasing over the years whereas; the mean maximum temperature has been increasing. Small-scale farmers' perception of climate change within the study area corroborated findings from the analysis of the meteorological data – increasing temperature and decreasing rainfall over the years. The probit model revealed that the perception of climate change was significantly influenced by the years of residence in the study area, whether the farmer: received regular climate information, practiced subsistence farming, had received formal education, and had experienced impacts of climate change. In regards to the factors influencing the adoption of adaptation measures, the logit model revealed that the gender of the household head, farm size, education of the household head, and whether the farmer received climate information significantly determined adaptation strategy uptake. Therefore, to improve small scale farmers' preparedness for climate change and uptake of adaptation strategies, regular climate data and agricultural extension services should be made accessible to farmers through County or National Government's agricultural policy.

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LIST OF ABBREVIATIONS AND ACRONYMS

CEEPA	Centre for Environmental Economics and Policy in Africa
CDF	Cumulative distribution function
CO_2	Carbon dioxide
CRU	Climate Research Unit
E. G	For example
ET AL	And others
FAO	Food and Agriculture Organisation
GDP	Gross Domestic Product
GHG	Greenhouse gases
GOK	Government of Kenya
IFAD	International Fund for Agricultural development
IPCC	Intergovernmental Panel on Climate Change
ITCZ	Inter Tropical Convergence Zone
JRA55	Japanese 55-year Reanalysis
KNBS	Kenya National Bureau of Statistics
NCCRS	National Climate Change Response Strategy
NDMA	National Drought Management Authority
PR	Probability
RUM	Random Utility Model
SD	Standard deviation
SEI	Stockholm Environment Institute
UNFCCC	United Nation Framework Convention on Climate Change
USD	United State Dollars
WGII	Working group II

CHAPTER ONE

1.0 INTRODUCTION

This section presents the study's background, the problem statement, the objectives, the area of study and finally the study's justification.

1.1 Background of the Study

Changing climatic conditions pose extensive global implications (Stern, 2006; IPCC 2007, IPCC, 2014) which include extreme weather occurrences (Stern, 2006; IPCC, 2007; Karl *et al*., 2009). Scientific evidence indicates that there has been an increase in the average global temperature by 0.6 ± 0.2°C in the last century (IPCC, 2007), Further, rainfall has become erratic with increased drought conditions and short periods of heavy precipitation. (Shrestha *et al*., 2000).

Changes in rainfall and temperature have both positive and negative effects on agriculture which is one of the most climate dependent sectors in any economy (Stern, 2006). For example, in 2006: the productivity of cereal was estimated to be higher in Northern Europe and Russia due to the rising temperatures in regions that experience very low temperatures that are unsuitable for agricultural production (Belyaeva *et al.,* 2018) while the great 1998 flood in China inundated $21x10^6$ of crop land causing an economic loss of over US$20 billion (Zong and Chen, 2000).

Climate change has relatively more profound effects on developing nations than it does on developed countries (IPCC, 2001). For instance, most of Africa's nations low adaptive capacity and multiple stresses make it more susceptible to the changing climatic conditions. (IPCC WGII 2007). The low adaptive capacity is brought about by factors such as limited capital and technology access, depletion of natural resource base, extensive poverty, and inequitable distribution of resources. Foresight projections indicate that around 1300 million people in 2080 could experience hunger risk under extreme scenarios with the poorest countries extremely affected (Parry *et al*., 2004).

In Kenya, the agricultural sector plays a pivotal role in economic growth. At least 25% of Kenya's GDP is accounted for by the agricultural sector with 75% of the population depending on small scale agriculture for both food and income (Perret, 2006). However, Kenya's farmers are vulnerable to risks in agriculture arising from both climate and non-climate related events.

Additionally, the farmers rely on rain-fed agriculture and have specific planting seasons in a year. Therefore, any adverse disruptive event to a farmer's usual crop growing cycle has dire implications on agricultural production. In the recent past, Kenya experienced severe weather occurrences. Specifically, the country has faced intense and prolonged drought and heavy hailstorms. These weather events have had a direct bearing on food production.

The impact of global warming if left unabated has evoked intense discussions on both mitigation and adaptation (IPCC WGII, 2007). By definition, mitigation consists of anthropogenic actions aimed at decreasing the sources of emission of greenhouse gases (GHG). Adaptation, on the other hand refers to adjusting of the human and natural systems to actual climate or anticipated climate change as well as exploiting beneficial opportunities (IPCC, 2001; Smit and Olga, 2001; SEI, 2009).

Most climate change studies revolve around mitigation strategies and/or adaptation potentials. For example, Bryan *et al*. (2009) posits that, increasing land cover through afforestation and adjusting crop planting dates are good climate change coping mechanisms. Also, income diversification has been found to cushion vulnerable households against the consequences of the changing climate (Barbier *et al*., 2009; Roncoli *et al*., 2001). Closer to home, some studies point out that adaptation has to happen at the community level to be effective and facilitating adaptation of current practices is more efficient than to impose the nationally decided measures (Eriksen and Lind, 2009).

Each of the studies highlighted above has a crucial bearing on adoption of coping mechanisms. However, with the exception of Eriksen and Lind (2009), the aforementioned studies and most other adaptation literature differ in geographical scope from this study. Predicated on the negative-positive dual nature of the impacts of global warming, it would be somewhat far-fetched to generalize findings of one area that differs geographically from another, oblivious of the underlying differences in weather. Furthermore, this study adds a caveat of perception onto the adaptation literature, an aspect that is rarely looked into in literature.

Against the foregoing background, this study builds on climate change adaptation mechanisms literature. Specifically, it highlights the perception of smallholder farmers towards climate change and the measures they use to boost resilience, and respond to the effects of changing climate.

1.2 Problem statement

Most households in developing nations are dependent on rainfed farming. However, farming is also the most susceptible sector to impacts of climate change (UNFCCC, 2007) in these countries. Over-dependency on rain for crop cultivation by rural households and more specifically in Nyatike Sub-county, Migori County has led to increased vulnerability of small-scale farmers to the changing climate. Consequently, the livelihoods of farmers are negatively impacted. It is evident that over the last 10 years, droughts and floods have persisted world over raising the levels of malnutrition and hunger in developing nations (FAO, 2011). In Kenya, global warming has indirectly led to a rise in cases of food insecurity, hunger and malnutrition.

Despite the documentation of an array of climate change coping mechanisms adopted globally, the determinants of choice of an adaptation strategy have not been comprehensively studied and documented. Particularly, Kenya's small-scale farmers' climate change adaptation and mitigation strategy portfolio is unclear. Therefore, assessing small-scale farmers' knowledge base and their choice of adaptation strategies is necessary. Such information is vital to develop optimal intervention measures that would reduce vulnerability and guide the future adaptation strategies by small-scale farmers in the region to enhance their resilience towards climate change.

1.3 Objectives of the Study

The overall goal of this study was to assess small-scale farmers' perception and adaptation strategies to climate change.

1.3.1 Specific Objectives

To address the overall goal, this study sought to:

i. To determine the rainfall and temperature patterns in Nyatike subcounty

ii. To determine the climate change perception of small-scale farmers

iii. To examine factors influencing Nyatike subcounty small-scale farmerss' climate adaptation strategy choices.

1.4 Hypotheses

The following hypotheses were tested:

1. The climate of Nyatike sub-County has changed.
2. Small-scale farmers of Nyatike sub-County respond to climate change, albeit differently.
3. Identifiable factors shape the selection adaptation measures to climate change.

1.5 Justification and Significance of the study

Nyatike is a semi-arid region with limited water resources hence, changes in rainfall patterns increases the susceptibility of resident communities to the impacts thereof. Particularly, the climatic changes adversely affect agricultural production including reducing yields.

The greater concern of climate change on small scale farming justifies the necessity for a thorough study on adaptation and mitigation measures. The results derived from this study will benefit small-scale farming in Kenya through informed policy formulation, and subsequently on Kenya's economy that largely relies on Agriculture. Further, the results will add to the dearth of literature on climate change adaptation.

1.6 Area of Study

This section describes the location, soils and drainage, present land use, demography, and climatology of the area of study.

1.6.1 Location of the Study Area

Nyatike Sub County is located in Migori County The study area location is between longitudes 34 0 10`0"E and 34 0 20`0"E and latitudes 10 0`0"S to 00 10`0``S in the South Western part of Kenya.(see Figure 1).

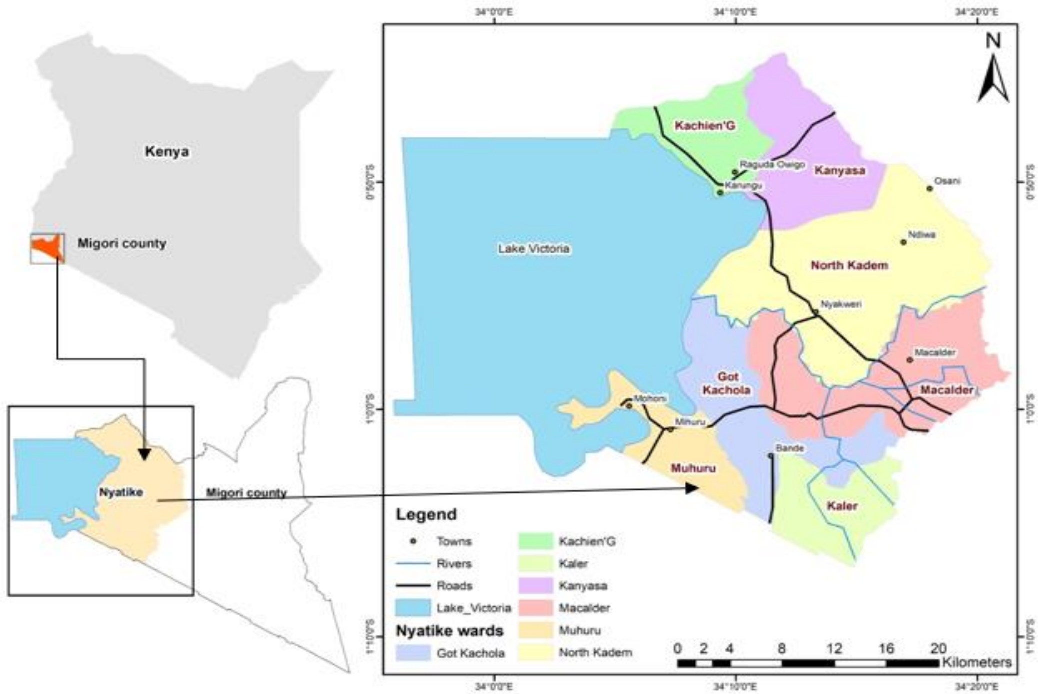


Figure 1: Map showing wards in Nyatike sub-County

Source: Author

1.6.2 Climate

Nyatike Sub-County experiences an equatorial climate with modification of temperatures caused by the humid winds from Lake Victoria. Nyatike is located at the shores of Lake Victoria with an altitude of 1140m. The study area's climate is strongly affected by its location and altitude in relation to Lake Victoria.

The study area experiences a mean annual rainfall of between 700 mm and 1,800 mm. Annually, there are two seasons of rain with high intensity precipitation occurring in the first quarter of the year, whereas low intensity precipitation occurs in the fourth quarter with dry months in between the two seasons. The migration of the Intertropical Convergence Zone influences the seasonal rainfall in the region. Annual temperatures range between 24 degree Celsius and 31 degree Celsius (County Government of Migori, 2018) with high humidity and a latent evaporation of 1800mm to 2000 mm per year. The climatic condition favors the cultivation of sugarcane, which is the county's main industrial crop, tobacco, maize, cotton, and cassava (Ministry of Planning and Development Plan, 2002).

1.6.3 Soils and drainage

Metamorphic rocks characterize the geology of Migori. The major rock types in this location include silts, diatomite and clay. The underlying parent in rock in most parts of the study area is granite. The soil type favors vegetable cultivation as well as sugarcane, maize, beans, coffee and groundnuts (County Government of Migori ,2013).

1.6.4 Present land use

The average land size for small-scale farmers and large scale farmers in the county (see figure 2 below) is 3 acres and 7 acres respectively (County Government of Migori, 2018). Most of the people in Nyatike practice subsistence farming of crops and livestock, while a substantial number intercrop maize with sorghum. Notably, horticultural crops such as tomatoes, kales and tobacco are grown at a small scale. Sugarcane is also grown in the county under contractual terms between the farmers in the region and the SONY sugar company (Bundeh, 2018). Majority of the locals in the area also keep indigenous cattle and chicken around their homes with some practicing charcoal burning. There is also existence of gold deposits in the study area.

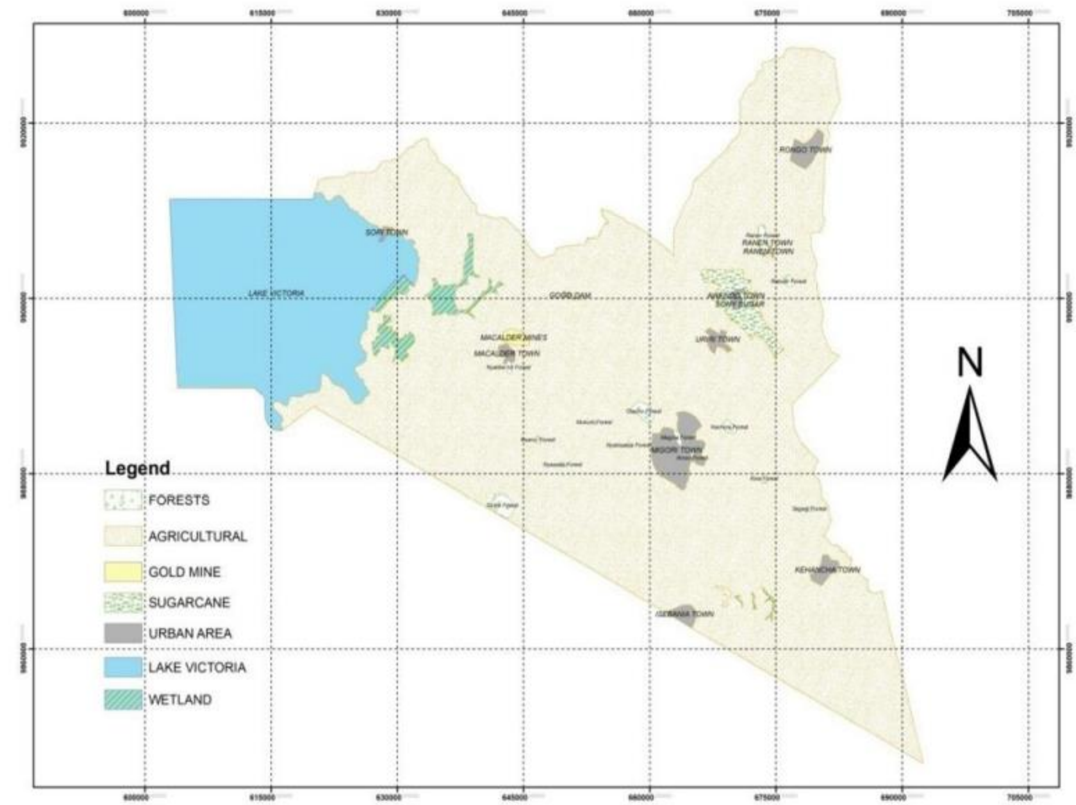


Figure 2: Migori County Land Use

Source: Survey and Physical planning Department, 2017

1.6.5 Population size and economic activities

Nyatike sub-county has a total population of 144,625 people with 30,423 households. Out of the total population 69,209 are males and 75,416 are females. The population density stands at 213 persons per square kilometers (KNBS, 2013). The growth of Macalder mines is one of the determining factors to population distribution in the area. The study area’s economic activities range from small-scale farming, fishing to trading and small-scale mining activities.

CHAPTER TWO

2.0 LITERATURE REVIEW

This section defines adaptation in the climate change context followed by highlights of relevant literature review of studies conducted in the region of the study area and other parts of the world.

2.1 Climate change Overview

Climate change is the variation in the state of climate as a result of either natural variability or human induced activities over a given area that lasts for an extended time period (IPCC, 2007). Climate change is a global problem, but the consequences and vulnerability vary across the globe. Climate variability and climate change are already having a negative impact on Africa, particularly on its small-scale farmers, who constitute the majority of the population that is economically active (FAO, 2016).

Although climate change is a global crisis, poor countries and individuals are increasingly affected in different ways. In Kenya, climate change is acknowledged among the biggest threats to growth facing the economy in the current century (Government of Kenya, 2010). Recent temperature increases and the erratic nature of rainfall patterns in Kenya make the climate change phenomenon a reality that cannot be wished away.

Climate affects resources that are critical for economic development. For instance, the climate-related La Nina droughts of the year 1999/2000 rendered nearly 5 million Kenyans food insecure. Similarly, disease causing vectors like plasmodia that cause malaria thrive in areas with increased average temperatures. In fact, Kebede *et al*. (2010) and Government of Kenya (2010) estimate the annual direct costs of climate damage if left unabated could potentially surpass the USD 1.5 billion by 2030 and considerably higher if indirect costs are added.

In 2010, the Ministry of Mining and Natural Resources (currently the Ministry of Environment and Forestry) of Kenya established a policy document, the NCCRS, that will integrate climate change information in the development agenda for the country. The NCCRS seeks to support and to direct national activities towards coping with the changing climate and greenhouse gas emission reduction. One of the key objectives enshrined in the NCCRS mission statement is the evaluation of evidence, and the consequences of a changing climate in Kenya through scientific research. Part of the assessment of evidence includes assembling information on perception, adaptation strategies, and impacts of climate change from small-scale farmers – the largest share of farmers – of Kenya.

Kenya prioritizes efforts of adapting to the changing climate in the Climate Change Adaptation Strategy 2009-2030 policy document. Particularly, adaptation of the agricultural sectors is critical because the sector concerns the national food security (GoK, 2013). To sustain the recent agricultural growth in the country, the government of Kenya has launched a number of strategies, policies and governmental bodies including, the Agricultural Sector Transformation and Growth Strategy 2019 – 2029, NDMA in 2011, and the NCCRS in 2010.

2.2 Rainfall and Temperature variability

Rainfall and temperature are the two significant climate factors influenced by changes in climatic conditions and global warming. The temperature increase, depict a rise in greenhouse gas emissions like nitrous oxide, ozone, chlorofluorocarbons and methane which render the earth warm by trapping more of the heat hence causing a greenhouse effect (El Zein *et al.,* 2015).

Temperature rise has been consistent since the mid-twentieth century and this trend will continue even in the future with scientific data indicating that temperature increased by 0.74 ± 0.18 °C in the last a hundred years (IPCC,2007. Most of Africa has experienced a rise in temperature by more than 1 degree Celsius, since 1901 while precipitation patterns in the past reveal that majority of Africa is getting drier (Hartmann *et al*., 2013) with a decrease in precipitation observed in West Africa nations, Zambia and Zimbabwe while South Africa, North Africa and a part of East Africa have experienced an increase in precipitation (Girvetz *et al*.,2014).

Natural forces such as the ITCZ migration and the El Nino Southern Oscillation (ENSO) influence climatic variability within the East Africa region. The region experiences long rains in March-April-May and short rainy season in October-November-December. The main climate trends in the region that have been observed include a decrease in the long rains and an increase in the short rainy season, longer drought periods and intense flood events. (Nicholson *et al*., 2017).

Since 1960, average yearly temperatures have risen by one-degree Celsius in Kenya (McSweeney *et al.,* 2009). Projections on precipitation are more uncertain compared to temperature projections. Precipitation projections under a high emission scenario project a decrease in the average annual precipitation in Southern Africa, West Africa and Northern Africa while an increase in annual average precipitation are anticipated over Central and Eastern Africa commencing in the 2050s (Girvetz *et al*., 2019). Also, by 2025, projections indicate that yearly precipitation in Kenya will drop by 50 to 150 millimeters in most parts of the country Funk *et al.* (2010). Particularly, long rains are expected to decline in most of the regions by 100 millimeters or more.

2.3 Prior studies on climate change perceptions

Literature on the perceptions of climate is wide. However, it can be categorized based on the subjects from whom perception is drawn. Subjects hold varying opinions about climate change based on the domain they interact with. In particular, there are subjects who interact with the biodiversity, coastal zones, water resources, and agriculture. The actual subjects could include, personnel of major water companies, environment agencies, and non-governmental organizations whose perception of climate change vary.

Shackley and Wood (2001) study done in England find that the views that people bear on climate change depend mainly on if climate change fits into a specified reference setting that is primarily keen on management of resources on short-term basis. Anthropology, sociology, cultural psychology, and behavioral decision research have been identified by Weber (2010) as the broad areas that help shape the perceptions people have towards climate change. Pointedly, some rely on scientific research although through news media and not necessarily reading research articles. Consequently, individuals depend on expertise and evidence to build views about changes in rainfall and temperature patterns which in turn are underpinned by attention and trust. The former is a rare resource whose scarcity is exacerbated by the information load available on climate change. Therefore, for statistical evidence to be accepted as information that would influence perception and behavior the general public must attend to it (Weber, 2010).

2.4 Adaptations to climate change in agriculture

Scholars who undertake research on climate change report mixed results i.e., climate is changing in their geographical areas. For instance, while Deressa *et al.* (2009) report nearly one half of surveyed farmers within Nile Basin of Ethiopia experienced increased temperatures, in the past 2 decades and fifty three percent of them experienced low precipitation during the same period, Ishaya and Abaje (2008) found Jemaa farmers of Nigeria to be unaware and lacked the knowledge necessary to determine whether indeed climate had changed. Conversely, climate change coping mechanisms, in farming systems is shaped by perception as well as risk management choices to adverse weather events (Wang *et al.,* 2009). Moreover, the characteristics of resource systems impacted or that could potentially be impacted by adverse weather elements and the perceptions of associated risks are important in understanding human coping strategies and adjustments to the changing climate.

In Deressa *et al*. (2009), farmers who reported climatic changes over the previous 2 decades adopted adaptation measures. Farmers who recognize climate change therefore, would cushion themselves by taking up adaptation measures. Among the adopted farm related adaptation strategies in African countries, crop diversification, livestock rearing, irrigation, and integrated soil management are the most used (Kabubo-Mariara 2008; Mideksa 2010; Ajao and Ogunniyi 2011).

Studies on determinants of adaptation among farmers emphasize 3 broad categories of factors that shape adaptation strategy choice. The categories include i) socioeconomic and sociodemographic factors, ii) environmental factors, and iii) institutional factors (Komba and Muchapondwa, 2012; Asrat and Simane, 2018). Socioeconomic factors are the societal and experiences within the economy that shape a farmer's traits, her opinion and way of life. Environmental attributes include the physical terrain of the area where farming is practiced and the prevailing weather conditions. Finally, the institutional factors include access to information on climate change and to credit for farm input, and availability of farm extension services.

Deressa *et al*. (2009) finds that socio demographic and socioeconomic factors namely age, education attainment, size of household, marital status, whether the head is male or female, and livestock ownership among others influence how farmers adapt to climate change. Specifically, adoption of sustainable climate change adaptation technologies has been found to be shaped by age, whereby, farmers of ages between 15 and 35 years are likely to take up new innovative approaches and/or adopt early (Muzamhindo *et al*., 2015). Also, Asrat & Simane (2018) find that education positively associates with both perception and adaptation decisions because educated farmers are cognizant of the threats of the changing climate.

In principle, education enhances rational potential and responsiveness of farmers to adaptation innovations and therefore persuades them to adopt. Influence of gender on the decision to adopt has mixed results. While Asrat and Simane (2018) and Guteta and Abegaz 2015 find a positive and significance association between gender and uptake of strategies to adapt to climate change, the Human development report (2011) asserts that women and women-focused organizations demonstrate awareness and ability to lead successful response and preparedness towards a disaster, and recovery efforts within their society. The type of relationship status i.e., whether married or not is also highlighted in literature as having a bearing on how farmers adapt to climate change. Specifically, there is literature arguing that respondents in a marriage set up are more likely to explore new technologies because the risks underlying the decision are distributed between the husband and wife (Oberhauser and Pratt 2004).

Similarly, both household and farm sizes have been found to be positively associated with the uptake of mechanisms to cope with climatic changes. In particular, a larger household size is able to supply the required labor requirements to none-farm activities for most climate change adaptation measures (Gautam and Andersen, 2016; Rahut and Micevska Scharf, 2012), including building of water reservoirs for irrigation during droughts and soil conservation in cases of floods. Gbetibouo (2009) finds that the number of years lived in a particular location influences both decisions on perception and on choosing adaptation measures. This is explained by the level and duration of exposure to the weather conditions of a particular region which enables famers to make informed decisions on whether to adopt a technology.

Environmental factors that feature often in climate change literature on adaptation and perception include, occurrences of droughts, floods, agro-ecosystems, farmers' opinion on temperature and precipitation changes, and the mean yearly precipitation and temperature and the outcomes of climate change (Komba and Muchapondwa, 2012). Farmers who report fluctuations in precipitation and temperature, including increased incidences of floods and drought, are more likely to respond and adjust to climatic changes. The physical terrain of agricultural fields in specific agro-ecosystems also shape the choice of adaptation measures.

The social frameworks of engagement which are used to manage adaptation constitute the institutional factors. The mechanisms encompass legal regulation and enforcement instruments farming extension services, all of which determine adaptation. Farmers who are supported through external sources in terms of credit for farm input and market information for farm produce view and cope with changes in climate differently. For instance, awareness and credit access have been observed to boost adoption of coping mechanisms to credit (Nhemachena and Hassan, 2007). Similarly, Ishaya and Abaje (2008) indicate that farmers adopt coping mechanisms more likely if they are aware and/or more knowledgeable about climate change and adaptation. Similarly, inadequate capital and irrigation water have been found to shape adoption (Komba and Muchapondwa, 2012, Nzeadibe *et al*., 2011).

Each study highlighted above uniquely contributes to the climate change adaptation literature. However, what is critical for uptake is the accessibility, availability, and affordability of adaptation measures. Also, it should be recognized that the suitability of the chosen adaptation methods depends on the agro-ecological zones to which they are adopted which, in part, sets the scene for this study's contribution to literature. Besides this study's uniqueness in terms of its geographical area of study, it is also unique in how the outcome variable for analysis on adaptation is constructed. In addition, the inhabitants in this area have a unique interpretation of climate change and respond differently to impacts. Some apply traditional knowledge in their response while others use modern technologies to find solutions to climate change.

2.5 Conceptual framework

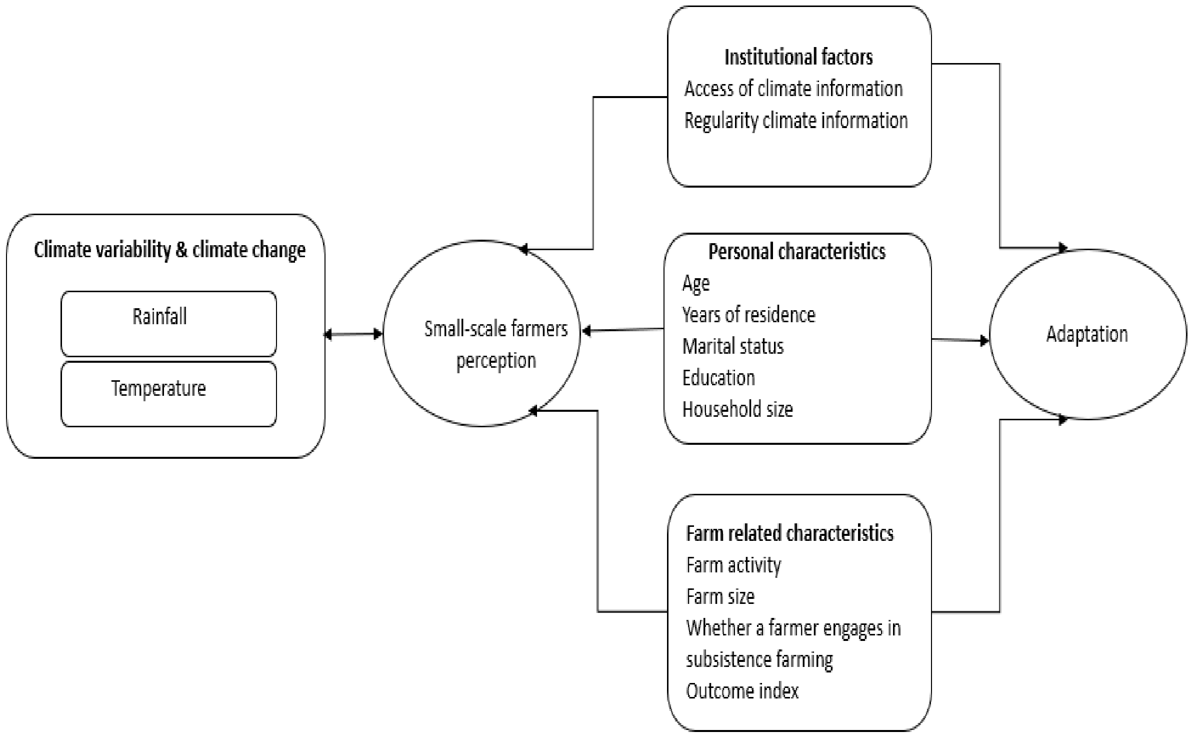


Figure 3: Conceptual framework

Source: Author

Figure 3 presents the conceptual framework illustrating the association between the two dependent variables (Perception and farmers' adaptation to climatic changes) and their respective explanatory variables. In particular, the hypothesis is that, personal attributes, institutional characteristics, and farm related attributes shape perceptions of climate change – hereby represented by changes in both temperature and rainfall (Figure 3). Likewise, personal attributes, farm related characteristics, and institutional factors were hypothesized to have an influence on the small-scale farmers' choice of climate change adaptation strategies.

2.6 Theoretical framework: The random utility model (RUM)

The empirical approach used to model both climate change adaptation decisions and perceptions is built upon the random utility theory (RUM). The theory involves utility maximization by the decision maker. The theory is founded on the psychological stimuli concept that was first developed by Thurstone (1927) and eventually led to the development of the binary probit and later the logit models. Afterwards, the stimuli concept was interpreted as utility and derived from utility maximization by Marchak (1960). Formally, individual *m* is faced with *J* alternatives (Train, 2009) from which to choose. Each alternative bears different levels of utility (*U*). From alternative *j* decision maker *m* obtains utility $U_{mj},\ j = 1, I, J$. The individual will select an alternative he draws the greatest utility from i.e.,

$$U_{mi,} > U_{mj,} \forall j \text{ ……………………………………………………………equation (1)}$$

where U_{mi} and U_{mj} represent decision maker *m*'s utility for alternative *i* and *j*, respectively.

The researcher on the other hand notes attributes ($x_{mj,}$) of the options available to the individual $\forall j$ and some characteristics of the individual, labeled S_n. The researcher can therefore specify a function that associates the observed factors to the individual's utility. Formally,

$$V_{m\,j} = V\,(x_{m\,j}, s_m)\ \forall\ j \text{ …………………………………………………...equation (2)}$$

where $V_{m\,j}$ is the representative utility that is dependent on parameters unfamiliar to the researcher and, thus estimated empirically. Because of the unknown, unobserved, and unobservable aspects of utility,

$$V_{mj} \neq U_{mj} \text{ ………………………………………………………………Equation (3)}$$

and utility is decomposed as

$$U_{mj} = V_{mj} + \varepsilon_{mj}, \text{ ………………………………………………………equation (4)}$$

where ε_{mj} includes the factors that influence utility but are not captured in V_{mj}. Since $\varepsilon_{mj}\ \forall\ j$ is unknown to the researcher, he treats these terms as random. Therefore, the joint probability distribution of the random vector $\varepsilon_m = \langle \varepsilon_{m1}, \ldots, \varepsilon_{mJ} \rangle$ is designated as $f\ (\varepsilon_m)$. Based on this probability distribution, the researcher can infer statistical statements about the individual's choice. Hence, the likelihood that individual *m* chooses option *i* is,

P_{mi} =$Prob$ (U_{mi} >$U_{mj)}$ $\forall j \neq i$

=$Prob(\varepsilon_{mj} - \varepsilon_{mi} < V_{mi} - V_{mj} \forall j \neq i)$. ……………………………………..equation (5)

The cumulative distribution is P_{mi} , i.e., the probability that each random term $\varepsilon_{mj} - \varepsilon_{mi}$ falls under the observed quantity $V_{\_i} - V_{mj}$. By using $f(\varepsilon_m)$, the cumulative probability can be rewritten as,

$$P_{mi} = Prob(\varepsilon_{mj} - \varepsilon_{mi} < V_{mi} - V_{mj} \forall j \neq i)$$
$$= \int_{\varepsilon} I(\varepsilon_{mj} - \varepsilon_{mi} < V_{mi} - V_{mj} \forall j \neq i) f(\varepsilon_m) d\varepsilon_m, \text{ …………………….. equation (6)}$$

where I(.) is 1 when the parenthetic expression is observed and 0 otherwise, $\int_{\varepsilon}$ integrates over the probability distribution for the portion of utility that is not observed, f (ε_n). The probit and logit approaches are derived based on the assumption that f (ε_n) is a multivariate normal and logistic distribution respectively. Simply put, the alternatives' observed attributes ($x_{mj,}$) and the decision maker characteristics (s_m) enter the utility function through a linear function that produces the familiar RUM,

$U_{mj}{}^{*} = \beta' X_{mj} + \alpha' S_m + \varepsilon_{im}$, ………………………………………………………equation (7)

where X_{mj} and S_m represent vectors of variables of alternative attributes and decision makers characteristics, respectively. The corresponding parameters, β and α are estimated statistically.

CHAPTER THREE

3.0 DATA AND METHODOLOGY

In this chapter, the data and methods used to address the objectives of the study in chapter 1 are presented.

3.1 Data

Acquisition of primary data was achieved by interviewing small scale farmers based on a semi-structured questionnaire. The developed questionnaire was pretested to evaluate consistency, clarity and avoidance of duplication. The scope of the primary data obtained included the respondent's gender, age, education level, income source, number of years of residence in the area of study, farmers' perception of changes in climatic conditions and adaptation practices adopted.

To examine the rainfall and temperature patterns in Nyatike sub-County, gridded observation datasets were obtained from the TerraClimate database, which contains high spatial resolution (~4 km) global monthly climate from 1961 to 2018, during the time of our retrieval. The data is a blend of the WorldClim data with the coarser CRU Ts 4.0 (New *et al*., 2002) and the 55-year Japanese Reanalysis (JRA55) (Kobayashi *et al*., 2015), formed by merging them in temporal domain to give a longer dataset at high resolution. The reason for the use of the satellite dataset is due to unavailability of meteorological data from ground stations.
See Abatzoglou *et. al* 2018 for a complete description of these data.

3.2 Sample and Sampling method

The study's target population was small-scale farmers within Migori County, Nyatike sub-County. Small scale farmers for this study are defined as farmers with minimal assets and cultivating a land area of less than two hectares (World Bank, 2003). The sample was chosen using multistage sampling. Within Migori, Nyatike subcounty was purposively selected for its dominant and growing small-scale farmer population. First, stratified sampling method was used to select the sub-locations within the sub-county by taking into cognizance the number of households present in each sub-location proportionate to the total number in the sub-county.

Secondly and lastly, simple random sampling was undertaken to identify households practicing small-scale farming within the sub-County.

3.2.1 Sample size determination

A total of 150 randomly selected inhabitants practicing small-scale farming in different sub-locations were interviewed. This number was arrived at using a sampling method proportionate to scale (Anderson *et al*., 2007). The procedure is defined by:

$$\boldsymbol{n = \frac{pqz^2}{E^2}} \qquad \text{equation (8)}$$

where n is the sample size, p is the proportion of the total population of small-scale farmers in Nyatike subcounty, $q = 1\text{-}p$, z = confidence level ($\alpha = 0.05$), E = acceptable/allowable error. Since the percentage of the households engaging in farming is not known, $p = 0.5$, $q = 1\text{-}0.5 = 0.5$, Z = 1.96 and $E = 0.08$. This gives a population sample size of 150 farmers.

Structured questions were administered to farmers through an interview method. As an ethical consideration, the farmers' privacy, confidentiality, and dignity was maintained throughout the research period.

3.2.2 Data Quality Control

Data quality assurance was conducted to unearth inconsistencies, and other errors in the data such as outliers. Additionally, data cleaning activities were also performed to improve the quality of the data for analysis. Mugenda and Mugenda (2003) indicates that a tenth of the total sample is appropriate for piloting prior to the actual field work, to fine tune the final research instrument. In line with this, 15 farmers were sampled in the pilot study. Pilot testing is important because it reveals ambiguous questions and unclear instruments.

3.2.3 Data Validation

The validity of the research instrument was determined through a pilot research. The method is to test the instrument on a smaller scale and adapt the instrument to the research to ensure accurate research (Robson, 2002).

3.3 Methodology

3.3.1 Objective one methodology: To determine the rainfall and temperature patterns in Nyatike sub-County

To determine the rainfall and temperature patterns in Nyatike sub-County, gridded observation datasets were obtained from the TerraClimate database, and regression analysis of the timeseries datasets was done to determine the temperature and rainfall patterns of the area of study.

3.3.2 Objective two methodology: To determine the climate change perception of small-scale farmers

The perception of climate change decisions made by farmers was analyzed using a binary choice econometric approach called the probit model. Binary models are suitable when the option between two alternatives is determined by the character of the subject in question (i.e. small scale farmers) (Pindyck & Rubinfeld, 1998). The general form of a probit model with a dependent variable $y \in [0,1]$ is as follows:

$\Pr(Y = 1|X) = \Phi(\mathrm{x}\beta)$ ……………………..……………………………………...equation (9)

with latent variable $y_i^p = x_i\beta + \varepsilon$, y =1($y^*$>0) …………………………………equation (10)

where Pr() is the probability, y_i^p is the outcome variable that takes the value of 0 or 1 for a yes or no response to perception of a farmer on selected long-term changes in mean climate variables, x is a set of independent variables that are expected to impact perception. The explanatory variables include sociodemographic and socioeconomic factors, environmental factors and institutional factors. Also, β is the parameter to be estimated for each explanatory variable and Φ() is the cumulative normal distribution (Wooldridge, 2002).

Empirical specification for perception of temperature and rainfall changes

$$Perc\_incrsd\_rnfall_1^* = \beta_1 + yr\_res_2\beta_2 + Sub\_farm_3\beta_3 + Farm\_act_4\beta_4 + Reg\_info_5\beta_5 + Out\_comeI_6\beta_6 + Rec\_info_7\beta_7 + Age\_hhd_8\beta_8 + Educ_9\beta_9 + \beta_{10} + Farm\_siz_{11}\beta_{11} + Hhsiz_{12}\beta_{12} + AdaptI_{13}\beta_{13} + \varepsilon_1 \text{....equation (11)}$$

$$Perc_{temp}{}_1^* = \pi_1 + yr_{res_2}\pi_2 + Reg_{info_5}\pi_5 + Out_{comeI_6}\pi_6 + Farm_{act_4}\pi_4 + Sub_{farm_3}\pi_3 + Out_{comeI_6}\pi_6 + Rec_{info_7}\pi_7 + Age_{hhd_8}\pi_8 + Educ_9\pi_9 + \pi_{10} + Farm_{siz_{11}}\pi_{11} + Hhsiz_{12}\pi_{12} + AdaptI_{13}\pi_{13}Mar\_stat_{13}\pi_{13} + \upsilon_1 \text{ .... equation (12)}$$

Table 1: Explanation of Variables used in the Equation

Key	**Description of variables used in the equation**
Perc_incrsd_rnfall	Perception of increased rainfall
$Perc_{temp}$	Perception of increased temperature
Yr_res	Number of years of residence in study area
Sub_farm	Do you practice subsistence farming
Farm_act	Do you practice crop related farming activities
Reg_info	Do you receive regular climate information?
Outcome_I	Number of outcome/impacts of climate change
Recinfo	Received climate information
Age_hhd	Age of the head of the household
Educ	Do you have a formal education?
Farm_siz	What is the acreage of your farm?
Hhsiz	Household size
Adapt_Index	Adaptation Index

3.3.3 Objective three methodology: To determine factors that influence uptake of adaptation strategies

The Logit model was applied to model the factors that influence selection of climate change adaptation actions. The outcome variable used to model farmers' adaptation to climate change was uniquely constructed. Crop-related strategies were selected from a list of strategies implemented by farmers to counter consequences resulting from changes in climatic conditions, including on-farm and off-farm adaptation strategies and were used to create an adaptation index.

Using the index, a threshold was set based on the number of crop related adaptation strategies a farmer adopted. Then, based on the index threshold – hence the level of adaptation, farmers who reported to have used more than 5 crop related climate change adaptation strategies were classified as high adopters (=1) (Table 2). Finally, the resulting binary outcome variable was used as the dependent variable, y = [0, 1].

Table 2: Frequency of Adaptation Strategies Adopted by Farmers

Index of adaptation strategies	**Frequency**	**Percentage**
0	10	6.67
1	10	6.67
2	18	12
3	16	10.67
4	20	13.33
5	22	14.67
6	21	14
7	26	17.33
8	2	1.33
9	5	3.33
Total	150	100

Thus, the decision to adopt crop related adaptation strategies (=1,> the threshold) or not is estimated using a binary econometric approach. Particularly, this analysis models the association between the decision outcome variable and; demographic, socioeconomic factors, environmental factors, and institutional factors. The logit model takes the general form of the dependent variable $y \in [0,1]$ (Wooldridge, 2002)

$E[y|q\beta] = G(q\beta),$ ………………………………………………………………equation (13)

where

$q\beta = \alpha + \mathbf{x}\gamma + \varepsilon$ ……………………………………………………………………equation (14)

has an intercept with coefficient α, a vector of independent variables, **x**, a coefficient of vector γ, a random error ε, and G () =Λ (), the logistic CDF. The logit approach models the decision to adopt an adaptation strategy or not while confirming estimates of responses for a specific set of small-scale farmers falling within the interval unit. Chi-square test is conducted to check the model's goodness of fit.

Empirical specification for the variables that shape the option of farm related adaptation strategies to climate change

$$Adaptation_1^* = \psi_1 + yr\_res_2\psi_2 + Sub\_farm_3\psi_3 + Farm\_act_4\psi_4 + Reg\_info_5\psi_5 + Out\_comeI_6\psi_6 + Rec\_info_7\psi_7 + Age\_hhd_8\psi_8 + Educ_9\psi_9 + \psi_{10} + Farm\_siz_{11}\psi_{11} + Hhsiz_{12}\psi_{12} + cop\_mechI_{13}\psi_{13} + \mu_1$$

……………………………………………………………………………….equation (15)

Based on the response of the shift in the explanatory variable, estimated coefficients for both the probit and logit models need an extra procedure to transform them into the likelihood of the change in the dependent variable. The transformation makes the coefficients interpretable.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSIONS

Statistical analysis results for each specific objective are presented in this section. The surveyed population was composed of small-scale farmers who resided in the study area for at least 30 years.

4.1 Determination of rainfall and temperature patterns

Decomposed time series of the rainfall in Figure 4 shows a significantly decreasing trend; see that the trend component fits a linear model significant at the standard 5% significant (p-value < 0.05). The computed student t-value is the statistic for the difference between means of the first-half and the second half of the study period, which shows that the mean in the second half shifted significantly.

The seasonal component indicate that the region has two main peak seasons in the rainfall pattern (on that peaks around May and another peak of interest during August) See figure 10. More analysis on significance of this seasonal component will be handled later in this study. The random component is exposed when the trend and seasonal components are subtracted from the original time series, leaving a series scaled to have a standard deviation of one.

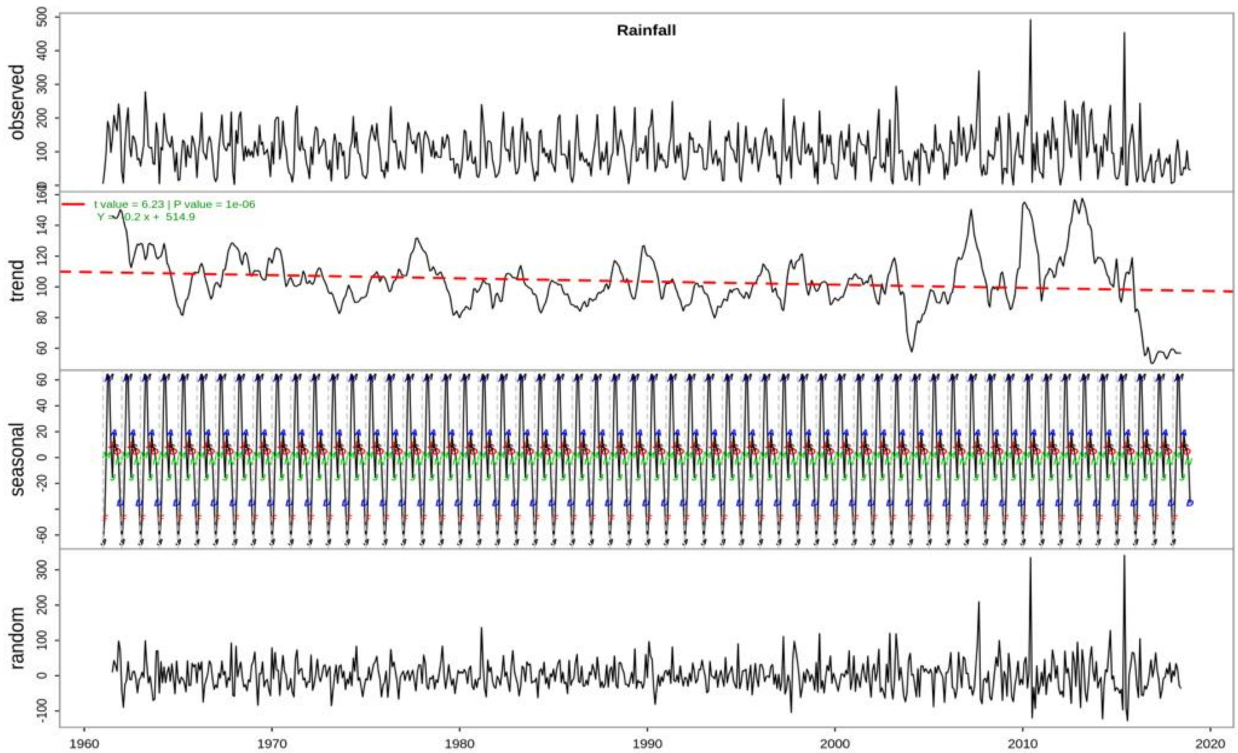


Figure 4: Time series plot of the observed rainfall over Nyatike

Decomposed time series of the Maximum air temperatures (Figure 5) shows a significantly increasing trend; see that the trend component fits a linear model significant at the standard 5% significant (p-value < 0.05). The computed student t-value is the statistic for the difference between means of the first half period and the second half study period, which shows that the mean in the second half shifted significantly. The analysis showed positive trend line(Y=0x-40.3) indicating an increase in maximum temperature over the years. More analysis on significance of this seasonal component will be handled later in this study. The random component is derived when both trend and seasonal components are subtracted from the original time series, leaving a series scaled to have a standard deviation of one.

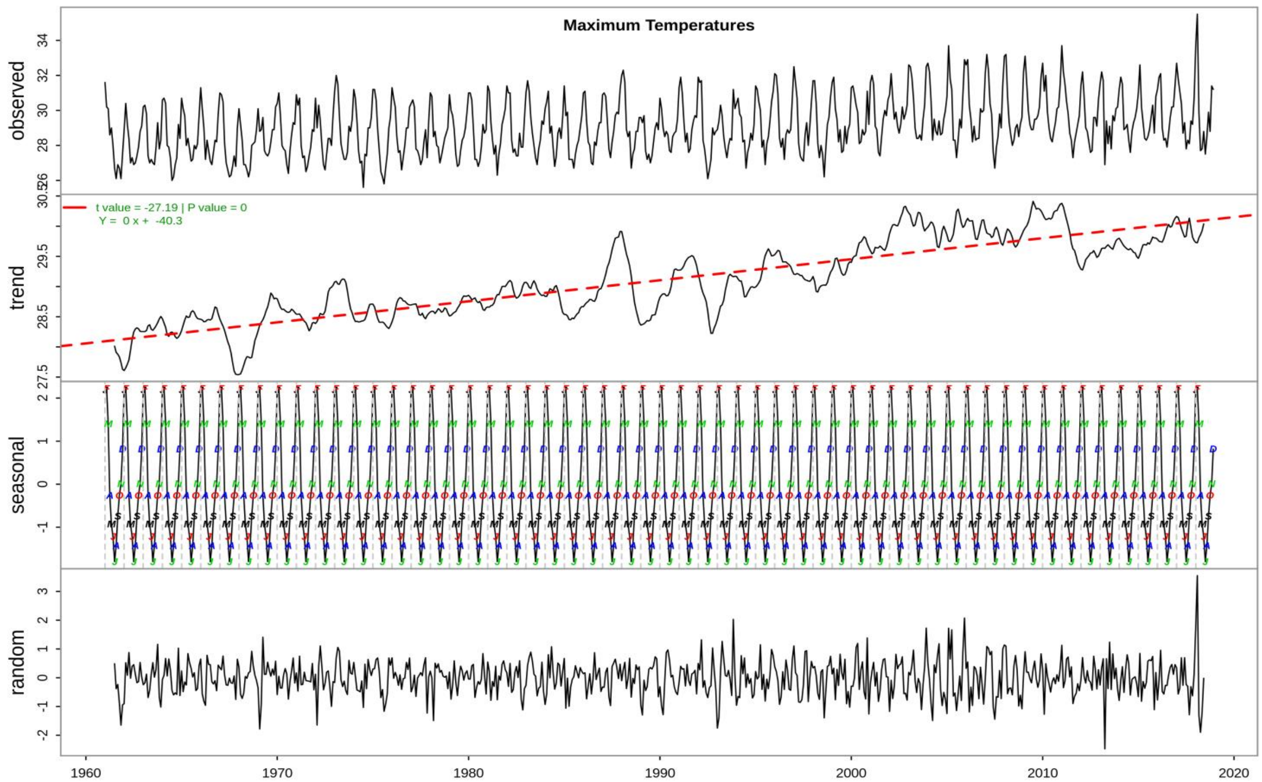


Figure 5: Time series plot of the observed Maximum air temperatures over Nyatike

Decomposed time series of the Minimum air temperatures (Figure 6) shows a significantly increasing trend; see that the trend component fits a linear model significant at the standard 5% significant (p-value < 0.05). The computed student t-value (+27.19) is the statistic for difference between means of the first half period and second half of the study period, which shows that the mean in the second half shifted significantly. The analysis showed positive trend line(Y=0x-49.8) indicating that maximum temperature increased over time.

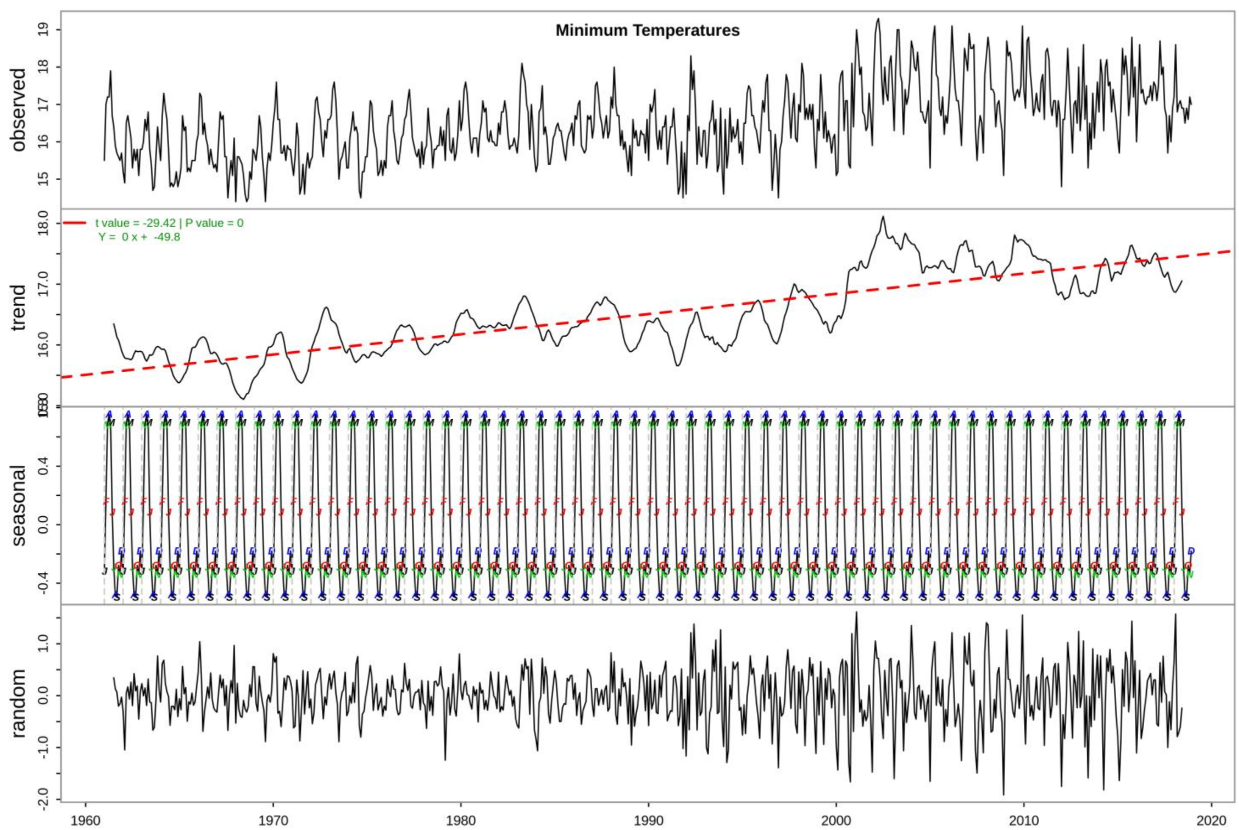


Figure 6: Time series plot of the observed Minimum air temperatures over Nyatike

More analysis on significance of this seasonal component is handled later in this study. The random component is derived when both trend and the seasonal components are subtracted from the original time series, leaving a series scaled to have a standard deviation of one.

As indicated in the Figure 7, rainfall shifted downwards in the latter climatology (1990 – 2018 years), compared to the former (1961 – 1989 years) (see axes of the plots in figures plotted on the same scale). The first climatology recorded the total annual rainfall basically around the mean value for the whole period, i.e. 1266.76mm while the second climatology showed varied annual rainfall from the mean for the period (especially the latter years of the second climatology). The mean for the second climatology is at 1209.79 mm. This shows a decreasing trend with increasing variability in rainfall during the two climatological periods considered

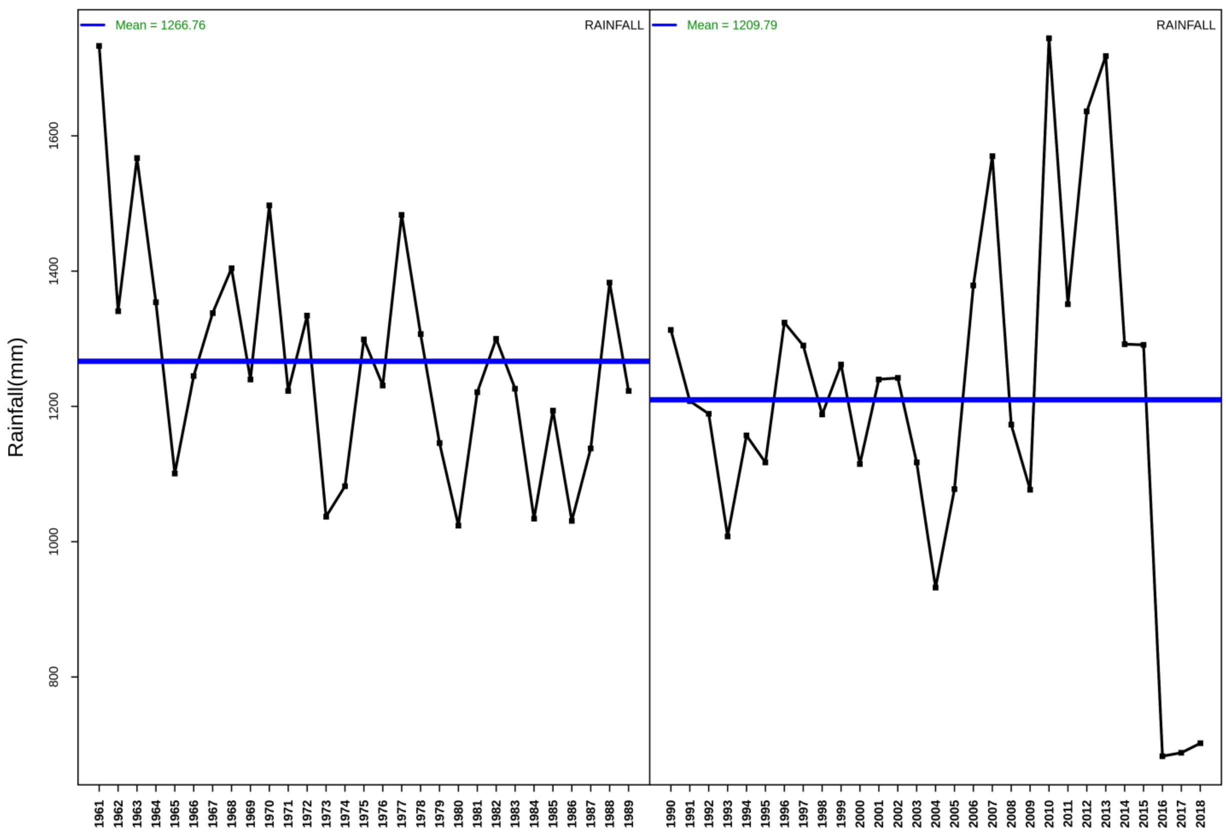


Figure 7: Time series plots of the total annual rainfall over Nyatike in two distinct climatological periods, clim1; 1961 – 1989 and clim2 1990 – 2018

Figure 8 shows the maximum temperatures shifted upwards in the latter climatology (1990 – 2018 years), compared to the former (1961 – 1989 years) (see axes of the plots in figures; they are plotted on same scale). The mean of the maximum temperature in the first climatology is 28.6 degree Celsius while in the second climatology the mean value increased to 29.61 degree Celsius.

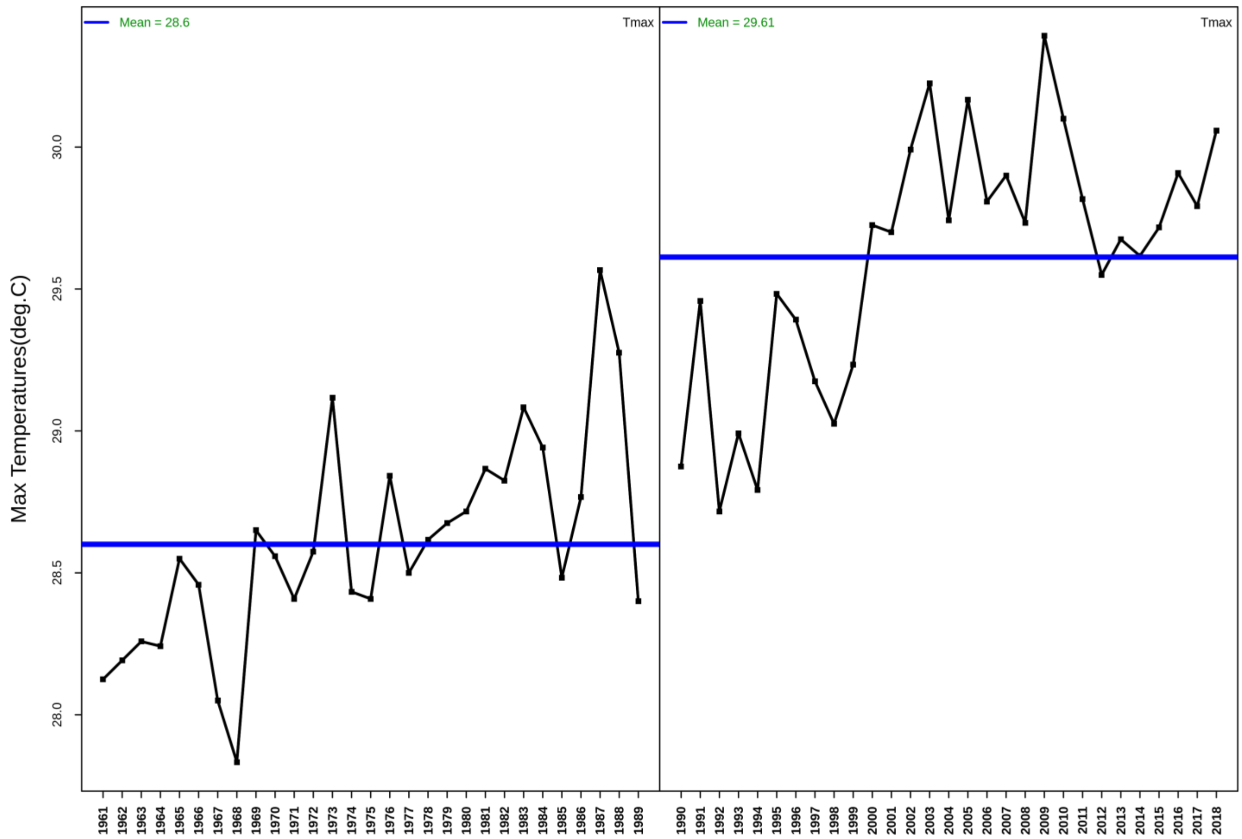


Figure 8: Time series plots of the average annual maximum temperature over Nyatike in two distinct climatological periods, clim1; 1961 – 1989 and clim2 1990 – 2018

Figure 9 shows the minimum temperatures shifted upwards in the latter climatology (1990 – 2018 years), compared to the former (1961 – 1989 years) (see axes of the plots in figures which are plotted on same scale). The mean of the minimum temperatures for the period 1961-1989 is 16.06 while that of 1990-2018 is 16.97 degree Celsius.

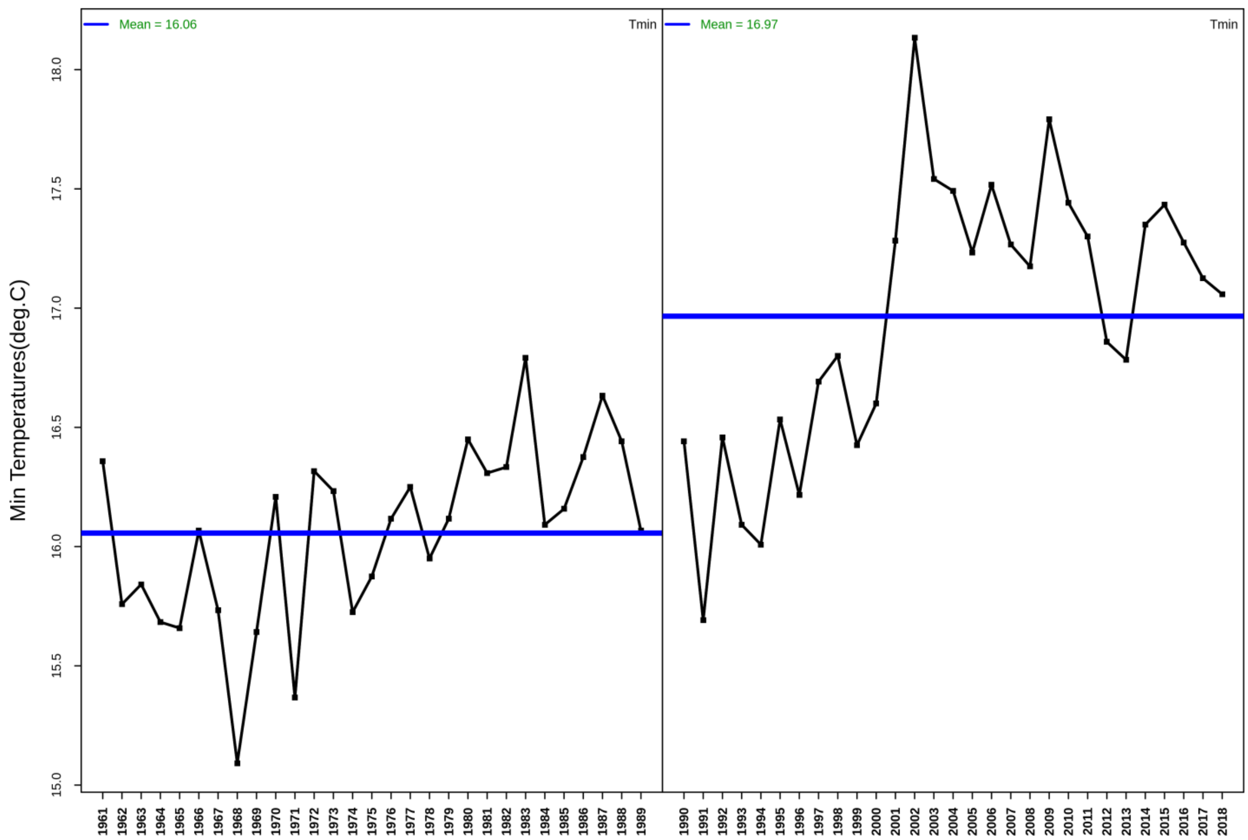


Figure 9: Time series plots of the average annual minimum over Nyatike in two distinct climatological periods, clim1; 1961 – 1989 and clim2 1990 – 2018

As indicated in the Figure 10 below, the study area has two main rainy seasons, indicated by pronounced peaks around March – April – May and another one peak from August through November, repeating in each year of the period of study. March to May season (long rains) showed decreased rainfall in the latter climatology (1990 – 2018 years), while the August to November season exhibited higher rainfall in the latter climatology (1990 – 2018 years) compared to the former (1961 – 1989 years).

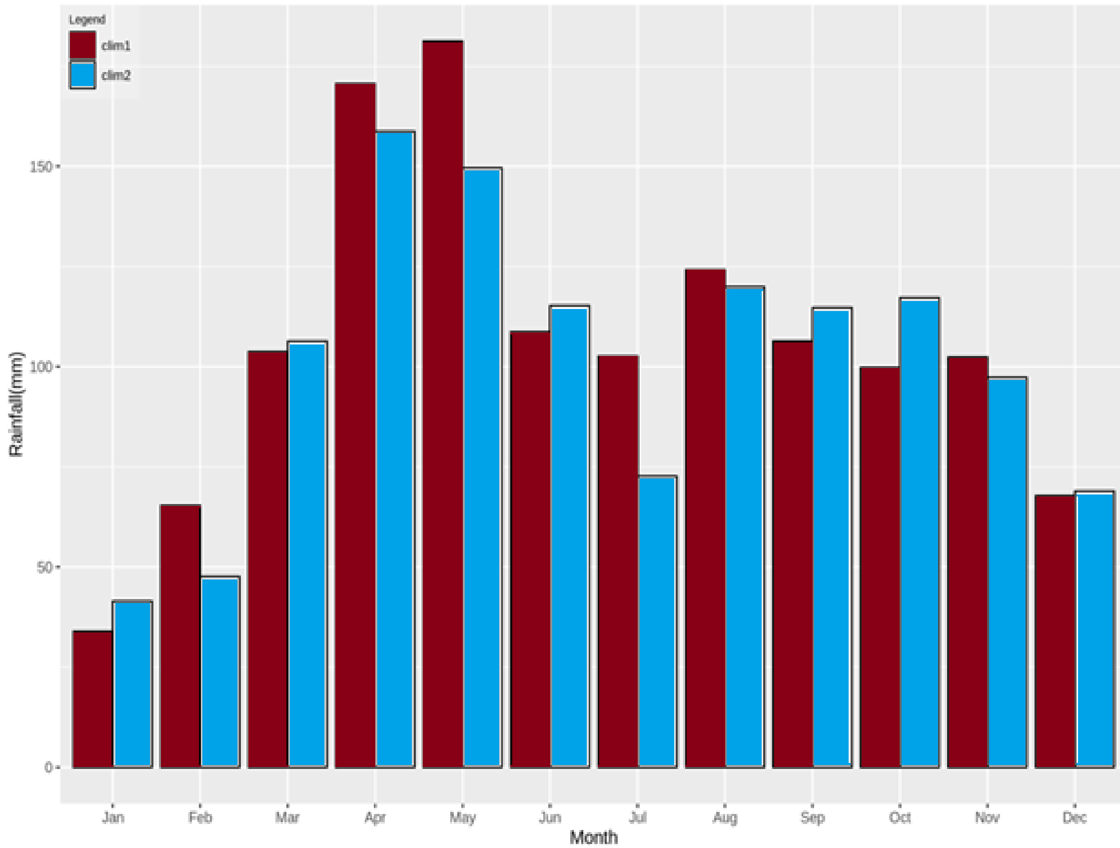


Figure 10: Bar plots of the Rainfall over Nyatike in two distinct climatological periods, clim1; 1961 – 1989 and clim2 1990 – 2018.

The maximum temperatures have pronounced peaks through the months of October to April the following year (Figure 11), repeating in each year through the period of study. A decrease in the maximum temperature is seen around the May to September seasons. Though these seasons of increasing and decreasing maximum temperature values are observed over the different months within the two climatological periods, generally, the latter climatology (1990 – 2018 years), exhibited higher temperatures compared to the former (1961 – 1989 years).

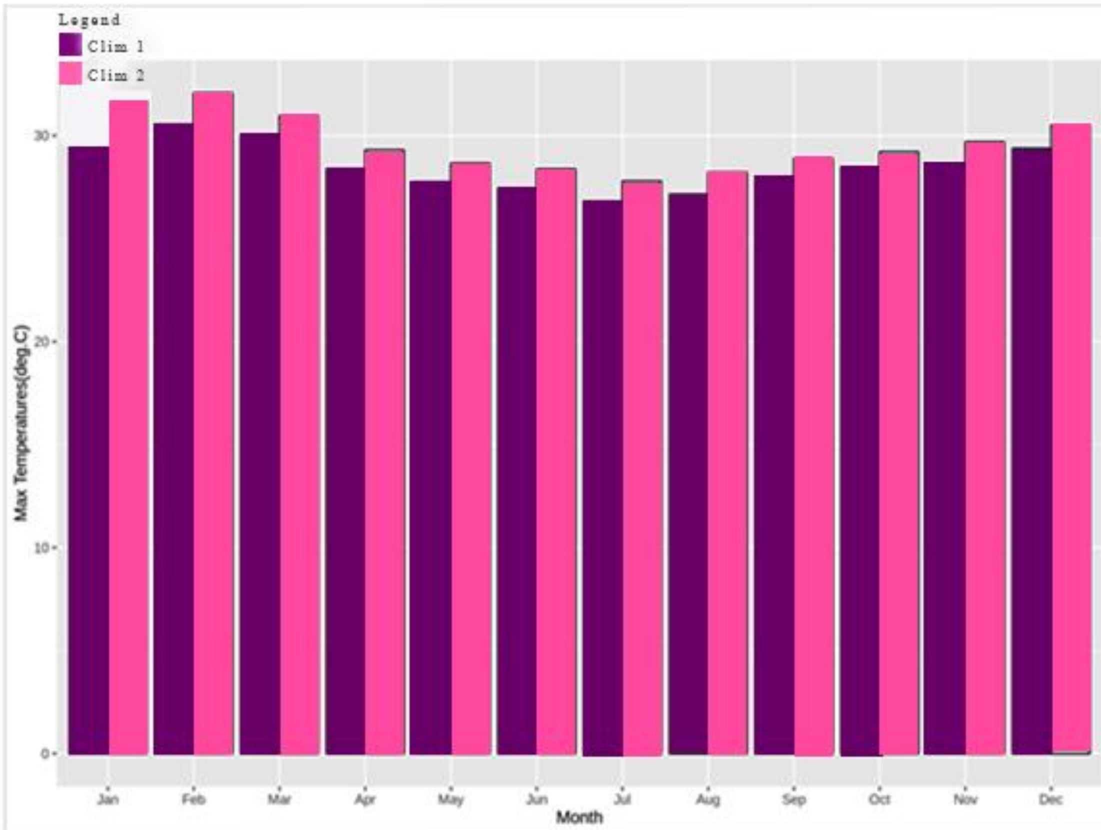


Figure 11: Bar plots of the maximum temperatures over Nyatike in two distinct climatological periods, clim1; 1961 – 1989 and clim2; 1990 - 2018.

As indicated in Figure12, minimum temperatures have pronounced peaks in March – April – May and another one in the October to December period. These peaks repeat each year of the period of study. A decrease in the minimum temperature is seen around the June to September seasons. Though these seasons of increasing and decreasing minimum temperature values are observed over the different months within the two climatological periods, generally, the latter climatology (1990 – 2018 years), exhibited higher temperatures compared to the former (1961 – 1989 years).

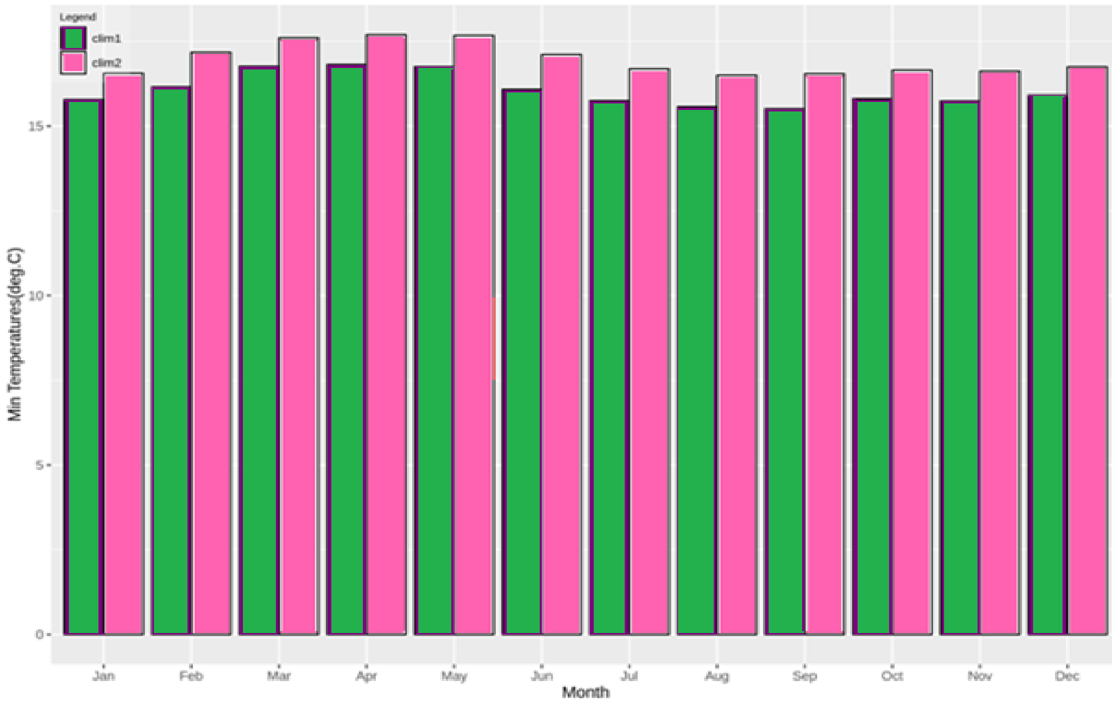


Figure 12: Bar plots of the minimum temperatures over Nyatike in two distinct climatological periods, clim1; 1961 – 1989 and clim2 1990 - 2018.

4.2 Variable description and descriptive statistics

4.2.1 Variable description

The description of variables included in the analysis were selected based on prior literature. With regard to education, farmers' educational attainment level is important because it enables a farmer to access and process new information. Age is a factor because it allowed gaining overall experience and ability to deal with changes in climatic conditions. The duration of residence in the study area enables the farmers to make comparisons of past and present climatic conditions albeit within a 30-year period requisite for climate change (IPCC, 2007).

Whether the household head is male or female is postulated to affect the level of commitment accorded to the climate change adaption measures (Asrat & Simane, 2018). Relationship status was a factor because of variation in decision making under different relationship set ups. Married individuals, for instance, are more likely to explore new technology because the risks underlying the decision not to adopt climate change adaptation strategies are distributed between the husband

and wife. Larger household sizes provided necessary labor requirements for the climate change adaption strategies which are mostly labor intensive.
The size of the farm was expected to proxy the effort a farmer accords the exploration of climate change adaptation measures. Also, whether a farmer received climate information and the regularity of the information, particularly on rainfall and temperature changes, could shape both her perception of climate change and her decision regarding adaption. The number of visible impacts/outcomes of climate change that a farmer was aware of or had affected her farm could also affect her perception and how she adapts to climate change.

Lastly, whether the farmer received external support including credit services for farm inputs, extension services for best farming practices, and climate change information could influence her decision process regarding climate change perception and adaption. Table 1 summarizes the expected coefficient signs of the explanatory variables from the logit and probit analyses.

Table 3: List of Explanatory Variables and Expected Signs of the Corresponding Coefficients

Variable code	**Variable name**	**Expected sign**	
		Perception	**Adaptation**
Yr_res	Number of years of residence in study area	+	+
Sub_farm	Do you practice subsistence farming?	+	+
Farm_act	Do you practice crop related farming activities	+	+
Reg_info	How often do you receive weather information	-/+	+
Age_hhd	What is the age of the head of the household?	-/+	-/+
Educ	Have you received formal education?	+	+
Farm_siz	What is the acreage of your farm?	-/+	+
Hhsiz	Household size	-/+	+
Adapt_Index	Number of climate change adaptation practices	+	
Outcome_index	Number of outcome/impacts of climate change	+	
Mar_stat	Marital status of the household head		
Cop_ mechI *Recinfo*	Coping mechanism to climate change Received climate information		

4.2.2 Descriptive statistics

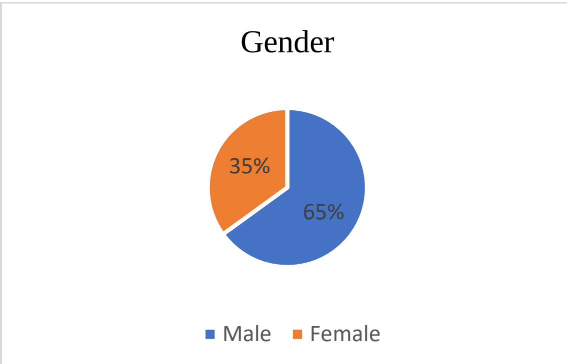
Table 4 displays the descriptive statistics for the used variables in the analysis

Table 4: Descriptive Statistics

Variables	**Mean**	**Sd.**
Age of household head	46.2	13.06
Sex of the head of household	0.65	0.48
Marital status of household head (married)	0.91	0.29
Number of years the household head has lived in the village	34.74	13.15
Source of household income for household head (subsistence farming)	0.89	0.31
Level of education of household head	0.35	0.48
Secondary activity for household head (Farm related activity)	0.67	0.47
From experience do you perceive that climate has changed	0.97	0.16
Has your household been impacted by climate change?	0.99	0.08
External support (1=Received in the within the last 10 years)	0.07	0.26
Do you receive any climate information (1=yes)	0.65	0.48
Outcome index of climate change	4.08	2.16
Indicator index of climate change	25.78	2.82
Coping mechanism index against climate change	2.07	1.54
Adaptation index against climate change	5.85	3.46
Household farm size in (acres)	3.2	1.19
Household size	5.61	1.75
Adoption of Crop related adaption strategies (1=yes)	0.67	0.47
Perception of increased temperature (1=increased temperature)	0.81	0.4
Perception of decreased rainfall (1= decreased rainfall)	0.83	0.38
Longer long rainy season (March, April, May) (1=yes)	0.25	0.44
Longer short rainy season (October, November, December) (1=yes)	0.11	0.31
Observations	150	

Socio-economic characteristics

On average, a household head was 46 years old, had lived in the study area for 34 years with a household of 5 members. Majority of household heads were men with, 65% being male and 35% being female as displayed in Figure 13 below. This is consistent with the finding by Auma *et al*. (2010) that male headed household tend to be more compared to the female headed households



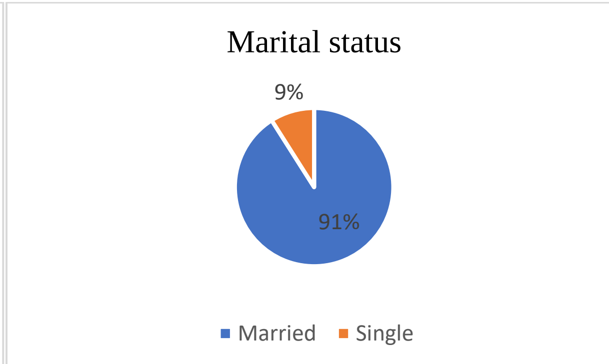
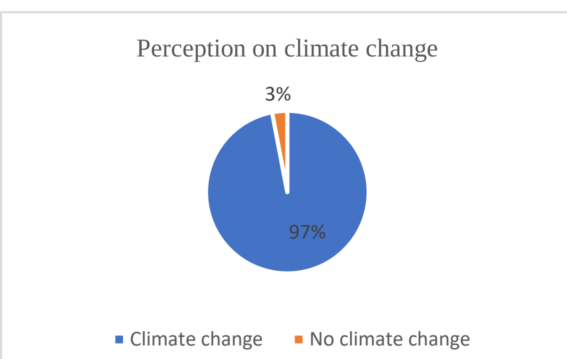


Figure 13: Gender and marital status of household head

Only 9% of the respondents indicated they were unmarried while the rest indicated they were single. Also, majority, 88%, of the respondents had obtained formal education while 22% had not. Most of the respondents, 89% engaged in subsistence farming while 67% relied on farm related activities as their secondary income generating activities. The average household farm size was 3 acres which corresponds to the average holding size of land for small-scale farmers in the county (County Government of Migori ,2018).

Perception of climate change

A large percentage, 97%, of the respondents said climate had changed within the study area with 99 % of them reporting they had been affected by the change.



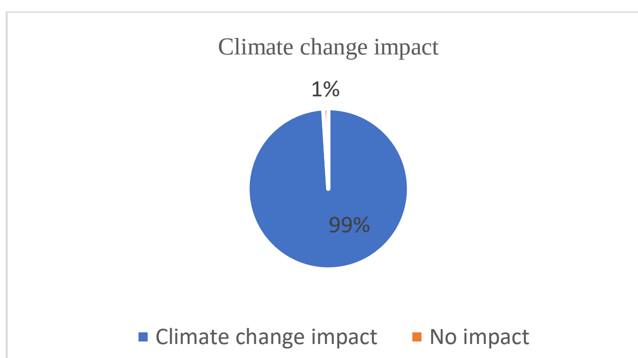


Figure 14: Perception and impact change in climate

Climate change outcomes and adaptation

On average, farmers said they had been affected by 4 out of 8 possible outcomes of climate change**.** An average farmer adopted 5 of 15 possible adaptation strategies. Among the adaptation strategies, 67%, of the smallholder farmers admitted to having adopted crop related adaptation practices yet only 7%, of the farmers indicated they had ever received external support for climate change adaptation within the previous ten years.

Perception by farmers on temperature and rainfall

A large percentage, 81%, of smallholder farmers perceived that temperature had increased while, 83% of them indicated that rainfall had decreased as shown in Figure 15. This finding coincides with other studies done in other parts of the world whereby farmers perceived rising temperatures and a decrease in rainfall. (Tambo *et al.*, 2013; Silvestri *et al*., 2012 and Barnes *et al*., 2012).

A quarter of the total sampled farmers said the long rainy season was not longer than it was 30 years ago. Likewise, nearly 11% of the farmers reported that the short rainy season was not longer than it used to be 30 years ago.

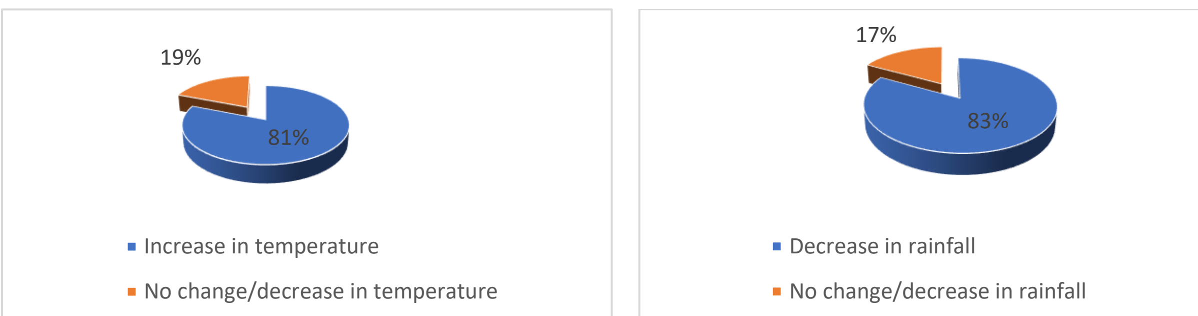


Figure 15: Perception of Farmers on Temperature and Rainfall

4.3 Probit model for determining farmers' perception towards climatic change and adaptation practices.

A schematic illustration links the smallholder farmers' perceptions of rainfall and temperature changes resulting from climate change (Figure 3). The perceptions are shaped by several groups of factors including: personal (household characteristics) and farm characteristics, climate change outcome, adaptation index, and institutional factors.

4.3.1 Decreased rainfall

The probit equations' estimation results regarding the perception of farmers on trends in temperature and rainfall are shown in column 2 of Table 5. Factors positively influencing small-scale farmers' perception of climate change indicators were: duration of residence within the study area, reception of regular climate information, engagement in subsistence farming, formal education, having farming as a secondary activity, crop adaptation index and climate change outcome index. Specifically, farmers who had resided in the study region for a longer duration of time over the years were more likely to perceive that rainfall had decreased. It could be that farmers who have a longer experience in years of the weather conditions in the study area are in a position to make objective judgements regarding the rainfall amounts. This aligns with the standard period of time under which climate change is considered to occur (IPCC, 2007).

Formally educated farmers were more likely to perceive that there had been a decline in rainfall resulting from climate change. This finding is consistent with the finding by Roco *et al*., 2015 who also established that education influences farmers' climate change perception positively. There is a possibility that education equips farmers with knowledge that enhances their capacity to make informed decisions about the volume of rainfall over the years (Ayanwuyi *et al.*, 2010). Subsistence farmers were more likely to perceive that rainfall capacity had decreased because of change in climate. Since farmers rely on rains to water the crops in the study area, farmers could be keen on timing and comparing the amount of precipitation volumes based on their farms' productivity. Although not entirely from higher rainfall volumes, subsistence farmers have been found to equate increased farm productivity to increased rainfall. Conversely, low output volumes would imply decrease in rainfall.

Also, the more crop related adaptation strategies a farmer has, the higher the likelihood she would indicate that there was a rise in rainfall due to climate change. The study area's flat terrain that is prone to flooding (nation.co.ke, 2018) could positively influence the perception that rainfall has decreased if indeed flooding does not occur as often as it used to. Farmers who regularly receive climate information are more likely to perceive that there has been a decrease in rainfall due to climate change. Regularly receiving climate information gives the farmers an information edge over their counterparts who don't receive it and thus are more likely to make informed decisions regarding rainfall patterns over a long period (Table 5). Similar to Ochenje *et al*. (2016) age had no effect on farmers perception on climatic changes.

To facilitate interpretability, an extra step was undertaken to convert the coefficients into the likelihood of dependent variable changing subject the explanatory variable changing. Although negligible, an additional year of residence in the area increases the probability of perceiving that rainfall had increased by 0.8% (Table 5, column 3). Similarly, formally educated farmers were 28.4% more likely to perceive that rainfall had decreased than their counterparts without formal education. Farmers with a farm activity as the second most important income generating activity are 11.7% more likely to perceive that rainfall had decreased due to climate change.

The probability of perceiving that rainfall had decreased increases by nearly 13.8% for farmers who reported to have received climate information. This finding corroborates Maddison (2006) who found that access to climate information shapes both perception of climate change and uptake of adaptation measures. Each additional crop-related adaptation strategy taken up by a farmer increases his probability of perceiving that rainfall had decreased by nearly 22.3%. Likewise, a farmer who experiences an additional impact/effect from climate change is likely to perceive that rainfall has decreased by nearly 2.3%.

4.3.2 Increased temperature

Column 4 of Table 5 presents the probit equation coefficient results on the perception farmers have of increased temperature due to climate change. Among the control variables, years of residency in the area of study, the type of secondary income generating activity, level of education of the family head, and the outcome index were found to impact smallholder farmers' perception of temperature change as a consequence of climate change. In particular, educated household heads are more likely to say there had been an increase in temperature as a result of climate change. Educated farmers are aware of the local climatic changes due to their ability to interpret and enhanced ability to utilize climate information. This finding concurs with other research (Uddin *et al*., 2017, Ndambiri *et al*., 2012)

Farmers who had a farm activity as a secondary income generating activity were much more likely to observe temperature increase as a consequence of change in climate. Due to the study area's relatively high and humid temperatures (Mukui *et al*., 2016), it could be that crop production volumes, have gone down due to climatic conditions fluctuations– including increase in temperature. The likelihood of perceiving a rise in temperature due to changes in climate increases with the number of years of residence within the study area. Also, the more the number of impacts from climate change, the higher the likelihood of perceiving an increase in temperature due to change in climate.

The coefficients (Table 5, column 4) were converted into the likelihood of the dependent variable changing as a result of the explanatory variable changing and are reported in column 5 of Table 5. Relative to their counterparts who were not formally educated, farmers with a formal education were 31.5% more likely to perceive that there had been a temperature rise due to climate change. Also, farmers with a farm related secondary income generating activity were nearly 20% more likely to perceive that temperature had increased in the study area. Similarly, each additional year of residence in the study area increases the probability of perceiving that climate change had caused an increase in temperature in the study area by nearly 0.6%. Lastly, having an additional climate change related impact/outcome from climate change increases the probability of a smallholder farmer agreeing that there had been an increase in temperature due to climate change by nearly 4.2% (Table 5).

Table 5: Regression Results for Farmer's Perception of Rainfall and Temperature

Variables	**Decreased rainfall (DR)**	**Marginal effects (DR)**	**Increased temperature (IT)**	**Marginal effects (IT)**
Years of residence	0.078^{***}	0.008^{***}	0.048^{**}	0.006^{**}
	(0.029)	(0.003)	(0.024)	(0.003)
Subsistence (1= subsistence farmer)	1.508^{*}	0.155^{*}	1.118	0.127
	(0.893)	(0.089)	(0.822)	(0.092)
Secondary activity (1= farming)	1.136^{*}	0.117^{*}	1.046^{*}	0.119^{**}
	(0.636)	(0.064)	(0.550)	(0.061)
Climate information (1= regular)	1.340^{*}	0.138^{*}	0.281	0.032
	(0.802)	(0.080)	(0.680)	(0.077)
Receiving climate information	-1.040	-0.107	-0.272	-0.031
	(0.671)	(0.067)	(0.615)	(0.070)
Age of household member 1	-0.018	-0.002	-0.038	-0.004
	(0.026)	(0.003)	(0.025)	(0.003)
Education (1 = formal education)	2.756^{***}	0.284^{***}	2.766^{***}	0.315^{***}
	(0.901)	(0.084)	(0.768)	(0.076)
Crop adaptation index	2.168^{**}	0.223^{**}	0.159	0.018
	(0.968)	(0.095)	(0.590)	(0.067)
Size of farm in acres	-0.098	-0.010	-0.167	-0.019
	(0.244)	(0.025)	(0.230)	(0.026)
Household size	-0.213	-0.022	0.001	0.000
	(0.150)	(0.015)	(0.155)	(0.018)
Outcome index	0.225^{*}	0.023^{*}	0.371^{***}	0.042^{***}
	(0.129)	(0.013)	(0.129)	(0.013)
Adaptation index	-0.165	-0.017		
	(0.114)	(0.011)		
Marital status (1=married)			1.105	0.126
			(0.815)	(0.091)
Constant	-2.117		-2.753	
	(2.058)		(1.760)	

AIC	123.665	.	134.013	.
BIC	162.541	.	172.889	.
Observations	147	147	147	147

Standard errors in parentheses
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

4.4 Logit model for determining farmer's factors influencing uptake of adaptation practices

Results of the variables that shape the selection of measures of adapting to climate change as conceptualized in Figure 3 are presented in Table 6. Some of the factors that were found to shape the choice of whether to adopt crop related climate change adaptation strategies or not (Table 6) are discussed below.

In particular, male headed households were less likely to adopt more than 5 crop related strategies to adaptation to manage the impacts emanating from climate change. The finding is consistent previous findings by Nhemachena and Hassan (2007) that small-scale farming is majorly done by women whereas men are more interested in non-farm activities. Hence, women are likely to undertake climate change adaptation measures than their male counterparts. Also, it could be that most men prefer engaging in mining, an alternative relatively profitable non-farm activity prevalent in the region.

Contrary to the findings by Obayelu *et al*. (2014) small-scale farmers who received formal education were less likely to adopt more than 5 crop related climate change adaptation strategy. It is possible that, being formally educated enhances a farmers' capacity to make an informed decision regarding the opportunity cost of engaging in farming relative to mining, a relatively more profitable income generating activity in the area (Oluwasola *et al*., 2008).

Contrary to the findings by Maddison (2006) farmers with access to climate information had a low probability of being adopters of more than 5 adaptation strategies. Receiving climate information may dissuade farmers from venturing into farming activities that are largely impacted by weather variability hence the negative association between receiving climate information and adaptation.

Unsurprisingly, farmers with access to climate change coping mechanisms were highly likely to take up adaptation measures. The fact that these farmers had coping mechanisms implies that they there is a high likelihood of them adapting to climatic changes by adopting strategies geared towards that direction.

Likewise, farmers with larger sizes of farm had a high likelihood of adapting to change in climate. This finding aligns with Sani and Chalchisa (2016) that climate change adaptation measures are considered more important by farmers who own relatively larger pieces of land because they tend to have more capital and resources to diversify against the risk of loss due to unexpected weather events.

Marginal Effects

A further step was undertaken to convert the coefficients into the probability of the changing of a dependent variable change as a response to an explanatory variable changing i.e., the marginal effects. Column 3 of Table 6 presents the marginal effects of the model. Male headed households were 14.4% less likely to adopt adaptation strategies than female headed households. Likewise, a farmer who had formal education was 29.8% less likely to adopt crop related adaptation measures relative to a non-educated farmer. Also, farmers were 23.5% less likely to adopt adaptation measures if they reported to have received climate change information.

Conversely, one additional climate change coping mechanism increases a farmer’s likelihood of adopting adaptation measure by 5.1%. Lastly, one additional acre to the farm size increased the probability of small-scale farmer adopting a climate change adaptation measure by 8.2%.

Table 6: Logit Regression Results for Factors that Influence the Choice of Climate Change Adaptation Measures Among Farmers

Variables	**Adaptation to climate change**	**Marginal effects**
*Age of the head of household	0.002	0.000
	(0.013)	(0.004)
Gender of the head of household (1= male)	-0.500*	-0.144*
	(0.279)	(0.078)
Marital status (1= married)	-0.138	-0.040
	(0.438)	(0.126)
Number of years of residence	-0.015	-0.004
	(0.013)	(0.004)
Education (1= Formal education)	-1.037***	-0.298***
	(0.321)	(0.082)
Subsistence (1= subsistence farmer)	0.116	0.033
	(0.425)	(0.122)
External support (1=receives external support)	0.549	0.158
	(0.608)	(0.174)
Climate information (1=receives climate information)	-0.818***	-0.235***
	(0.305)	(0.081)
Outcome index	-0.087	-0.025
	(0.075)	(0.021)
Coping mechanism index	0.179**	0.051**
	(0.085)	(0.023)
Farm size in acres	0.284***	0.082***
	(0.109)	(0.029)
Household size	-0.057	-0.016
	(0.076)	(0.022)

Regularity (1=receives climate information regularly)	0.287	0.082
	(0.324)	(0.093)
Constant	1.476*	
	(0.891)	
AIC	176.064	.
BIC	217.738	.
Observations	145	145

Standard errors in parentheses
* $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$

CHAPTER FIVE

5.0 CONCLUSIONS AND RECOMMENDATIONS

This chapter presents the study's conclusion, recommendations, and areas for future research.

5.1 Conclusion

The overall goal of this research was to evaluate how smallholder farmers perceive and respond to climate change given their farm-related characteristics, their personal characteristics, and the institutional factors under which their farming venture operates.

Decomposed time series of the maximum air temperatures and minimum air temperatures show a significantly increasing trend while rainfall shows a decreasing trend. This study finds that access to regular climate information, having a formal education, engagement in subsistence farming, and number of years of residence are crucial in shaping farmer’s perception on climate change. Farmers who are formally educated and who have access to regular weather information tend to perceive that indeed, there has been an increase and a decrease in temperature and rainfall respectively as evidenced by the timeseries analysis of the TerraClimate database. Eighty one percent of farmers perceive that temperature had increased while 83% perceived that rainfall in the area had decreased. Additionally, farmers who practice subsistence farming as their second most important income generating activity are more likely to perceive that climate has changed

On the other hand, farmer’s adoption of adaptation strategies was influenced by a number of factors. Famers with large farm sizes as well as those with a high number of coping mechanisms had a higher probability of adapting to climatic changes. Male-headed households, farmers with access to climate information and those who were formally educated on the other hand, were less likely to take up adaptation measures..

5.2 Recommendations

Small-scale farmer’s perception on climate is key in adopting adaptation strategies to respond to change in climate conditions. To improve small-scale farmers’ preparedness for climate change, regular climate data and agricultural extension services should be made accessible to farmers through County or National Government’s agricultural policy. The policy would ensure the dissemination of weather forecast data to the farmers. Similarly, farmers should be sensitized on the importance of adjusting to climate change and the implications their passivity to it on the food security in the country through the use of agriculture extension services.

Both government and the private sector should provide resources to build capacity of farmers and, hence, ensure there is efficient uptake of strategies of adaptation to lessen vulnerability and increase resilience towards climate change.

5.3 Areas for Further Research

Because the scope of this study is somewhat limited, future research on the cost benefit analysis of the listed adaptation practices would identify the most effective strategy suitable for small-scale farmers in Nyatike sub-County.

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APPENDIX 1 : HOUSEHOLD QUESTIONNAIRE

Introduction

Hello, my name is Erica Atieno, a Masters student of climate change at the University of Nairobi. I am carrying out a study on the perception and adaptation of smallholder farmers to climate change in Nyatike sub county. I will be grateful if you could answer a number of questions for me. Kindly respond honestly and accurately to questions listed below

Any answers you give will be completely confidential. Together with other smallholder farmers' information, your feedback will help inform policy on how smallholder farmers can be supported and cushioned from climate change.

Questionnaire number…………………………………………………………………….

Name of main interviewer……………………………………………………………......

Name of main interviewee……………………………………………………………….

Date of interview……………………………………………………………………....

Region…………………………………………………………………………………….

County…………………………………………………………………………………….

Sub County……………………………………………………………………………….

Ward………………………………………………………………………………………

Village…………………………………………………………………………………….

Mobile No. of the interviewée:…………………………………………………………

SECTION A

Sociodemographic information

Household structure 1a.

Names of the household head and members	Sex (**code 1**)	Age	Marital status (**Code2**)	Source of Household income (**code3**)	Number of years of residence in the village	Educational level (**code 4**)	Main activity (**code5**)	Secondary activity (**code5**)

Gender		**Marital status**		**Source of household inc**		**Education level**		**Activity**	
1	Male	1	Married	1	Subsistence farmin	1	Literate	1	Farming
0	Female	2	Single	2	Commercial	2	Primary	2	Animal Husb
		3	Divorced	3	Off-farm jobs	3	Secondary scho	3	Fishing
		4	Widow/widower	4	Vegetable producti	4	Tertiary	4	Business
		5	Separated	5	Remittance			5	Labourer
		6	Others	6	Civil service			6	Employee
								7	Others

SECTION B

FARMERS PERCEPTION ABOUT CLIMATE CHANGE

1. Comparing now to the 1980s, [30 year period] do you think climatic conditions have changed?

1. Yes 2. No

1.1b. If yes, what are some of the climate indicators that have changed?

S/N	Options	1)Agree	2.Disagree	Disagree	Strongly Disagree
1.2 b	Changes in temperature				
1.3 b	Increased temperature				
1.4 b	Decreased temperature				
1.5b	No changes in temperature				
1.6 b	Increased number of hot days				
1.7 b	Changes in amount of rainfall				
1.8 b	Increased rainfall				
1.9 b	Decreased rainfall				
2.0 b	No changes				

SECTION C

Climate Change Impacts	
1.0 c. Has your household been impacted/affected by climatic changes?	1. Yes 2. No
1.1 c. If yes, in above, which climatic event (s) has significantly affected your household over the past years?	1. Drought 2. Floods 3. Lightning 4. Landslides 5. Strong Winds 6. Heat waves
1.2 c What was the outcome of the event(s)	1. Decline in crop yield
	2. Crop failure
	3. Death of livestock
	4. Decline in livestock production
	5. Food shortage
	6. Increase in food prices
	7. Human Health problem
1.3 c How did you cope with the impacts of the climatic event (s)	1. Migrated to a new area 2. government/donor relief food 3. Assistance from friends/relatives 4. Sold asset (land, house, livestock) 5. Borrowed (bank, private money lenders, relatives and friends) 6. Sought off-farm employment 7. Household member migrated to other rural area 8. Reduced household food consumption

SECTION D

Farm adaptation Practices to climate change

1d. Which of the following adaptation measures have you undertaken?

	On-farm adaptation strategies	**1. Yes 2. No**	**Are you practicing it 1.Yes 2. No**	**Ranking**
	1.1d. Planting drought resistant crops			
	1.2d. Planting short duration crops			
	1.3d. Soil and water conservation mechanisms			
	1.4d. Diversification of crops			
	15d.Rain Water harvesting			
	1.6d. Changing planting time			
	1.7d Irrigation agriculture			
	1.8d. Charcoal burning			
	1.9d. Increased use of inorganic fertilisers			
	2.0d Mixed cropping system			
	2.1d. Use of hybrid crop varieties			
	Off-farm adaptation strategies			
	2.2d. Petty trading			
	2.3d Relying on remittance			
	2.4d Temporal migration			
	2.5d Changing diets			
	2.6d NGOs support			
	2.7d Government assistance			
	2.8d Skill jobs			
	2.9d Gold mining			
If No why haven't you changed your farming practice(s)?				
	1. Lack of credit services			

	2.Lack of equipment/machinery			
	3. lack of inputs(fertiliser /hybrid seeds)			
	4. Inadequate climate information			
	5.Limited access to extension services			
	6.Poverty			

How effective have the above adaptation strategies

Very effective ( ) Effective( ) Fairly effective( ) Not effective( )

Give a reason for your response above____

3e. Do you receive any regular climate information? 1: Yes 2: No

APPENDIX 2: RECOMMENDATION LETTER

Date: **11th March 2019**

TO WHOM IT MAY CONCERN

Dear Sir/Madam

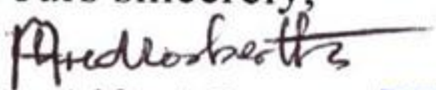
SUBJECT: Recommendation letter – Erica Atieno Onyango – I54/7705/2017

This is to confirm that above named is a bonafide student at the Department of Meteorology, University of Nairobi. She is a second year students pursuing Master of Science in Climate Change.

As a part of her course, her research project is entitled "**Assessment of small-scale farmers perception and adaptation to climate change in Nyatike sub county**" she would like to conduct household survey and Key informant interviews in Nyatike Subcounty in Migori County.

Any assistance offered to her will be highly appreciated.

Yours sincerely,



Dr. Alfred Opere

Chairman, Department of Meteorology

CHAIRMAN
DEPARTMENT OF METEOROLOGY
UNIVERSITY OF NAIROBI