# UNIVERSITY OF NAIROBI

## ANALYSIS OF THE EFFECT OF CLIMATE VARIABILITY AND SOCIO-ECONOMIC FACTORS ON ADAPTATION STRATEGIES AMONG SMALL SCALE FARMERS. A CASE STUDY OF NYANDARUA COUNTY, KENYA

**PhD THESIS**

**BY**


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**C80/52198/2017**


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**ACADEMIC THESIS SUBMITTED TO THE FACULTY OF ARTS AND SOCIAL SCIENCES & THE COMMITTEE OF POSTGRADUATE STUDIES IN FULFILMENT OF THE REQUIREMENT FOR THE DEGREE OF DOCTOR OF PHILOSOPHY (PhD) IN GEOGRAPHY AND ENVIRONMENTAL STUDIES OF THE UNIVERSITY OF NAIROBI, KENYA**

**NOVEMBER 2023**

## DECLARATION

I solemnly declare that this academic research thesis is my original effort which has not been presented to any other University; for examination or publication and in cases where other scholars work have been used, proper citations and referencing has been done as per the University policy.

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## DEDICATION

My mother (Reginah Wangui Muriithi) raised me with four other siblings in very challenging times after my father (The Late Samuel Muriithi) died when I was very young. In this regard, I am exclusively indebted to her and solemnly dedicate this academic research to her.

# ACKNOWLEDGEMENTS

I ascertain with gratitude the individuals that offered unmeasurable support during my PhD study. Primarily, special appreciations are directed to my supervisors: Dr. Boniface Nzuve Wambua and Dr. Kennedy Japhan Omoke. I appreciate their support, guidance, excellent academic mentorship, timely feedback, insightful criticisms and persistent encouragement during the study period. Family members encouraged me throughout the study period. My dear wife Magdaline Mumbi Njoki Ikua, our lovely children Lucy Wangui, Lewis Muriithi and Maryanne Njoki inspired me with their moral and spiritual support especially when I came home late and tired. My wife's encouraging words that it shall be well were very motivating to me. The prayers of my Mum, Reginah Wangui, and Brothers John Wamuti and Joseph Njeru gave me strength throughout the period. Special regards goes to Brother Wamuti for accompanying me as a research assistant in traversing Nyandarua County for data collection. My two sisters; Margaret Wanjiku Jasper and Gladys Wanjiru Bonnie accorded me unmeasurable welfare whenever I visited Nairobi for my Studies. I can't forget the well-being reception I received from my cousin Gladys Wanjiru Kinyanjui whenever I visited her for a sleep over during my studies. The positive criticisms, guidance and inputs by the lecturers at the University of Nairobi in departments such as geography, population and environmental studies and earth science were commendable. I sincerely thank the staff of Nyandarua County Government and the KMD at the head office and Nyahururu station for availing all the secondary data required. The field work and data collection would not have been successful without the cooperation of the respondents and key resource persons. My colleagues at Kiru Boys High School are thanked for their moral contribution and sustained encouragement during the academic study. Many of my friends encouraged and inspired me throughout the academic period. Above all, I am genuinely thankful to God because of his merciful providence of good health, a career, a family and finances to undertake this study.

# ABSTRACT

Climate variability and its impact on people's livelihood is a contemporary issue being discussed globally. The livelihoods of communities residing in Kenya's rural areas depend heavily on crop growing. For the optimum crop output, the sector is largely dependent on climatic factors like temperature and rainfall. Small holder farmers have applied several adaptation strategies to deal with varying rainfall and temperature patterns to maintain and improve key crop output. This study assessed the adaptation strategies adopted by the small-scale farmers to mitigate the effects of climate variability on their crop farming and output. The study adopted the Ricardian Model of using the primary and secondary data to assess and evaluate the effects of weather variability on agricultural output and adaptation. To achieve this objective, the study examined a 21 year mean annual rainfall and the temperature patterns from 1999 to 2019 and their influence on selected crop output (Maize and Irish potatoes). The study assessed and evaluated the effectiveness of adaptation strategies employed as well as the socio-economic factors influencing adaptation strategies in improving selected crop output. Frequencies of means, Pearson correlation, linear, multiple and the multinomial regression techniques were applied to analyse the data. The study found that rainfall variability significantly influenced about 50% of changes in maize crop output, but could not explain 91% of variation in Irish potato output. Maize output varied significantly between 1999 and 2019, with an average of 29,145.76 tonnes. Irish potato output showed increased trends, but output in tonnes also varied over the years. The study found minimal relationships between temperature changes and maize and potato output. The study rejected the null hypothesis that rainfall and temperature variability did not significantly impact crop farming in Nyandarua County. The study found that crop diversification was the most preferred form of adaptation, followed by planting new crops and adjusting planting dates. Income level positively influenced farmers' choice of crop diversification ($\beta$=0.067), while household head's education positively influenced shifting planting dates ($\beta$=.329). Land size and farming system negatively influenced farmers' key adaptation strategies ($\beta$=-0.091, p=-0.018). The hypothesis that socio economic factors do not influence the adaptation strategies adopted by small scale farmers was rejected. The empirical crop output model confirmed the respondents' and key informants' views that the adaptation strategies applied within 21 years were effective in maintaining and improving the crop yields. Multinomial logistic regression established that adoption of crop diversification and application of new crop variety were effective in increasing crop output (Exp ($\beta$) =1.981, Exp ($\beta$) =1.292, respectively). The study concluded that the primary strategy for maintaining a high crop output lies in bridging the gap of adaptation knowledge between the farmers' and the policy makers. The study recommends a continuous formulation and monitoring of the effectiveness of sustainable adaptations based on regional climate variability patterns, socio-economic considerations, existing government policies and spatial ecological environments. Research suggests that further study in Nyandarua County is needed to understand the interrelationship between climatic and agricultural factors, the costs of adaptation measures for smallholder farmers, and the impact of other agronomic factors.

## LIST OF ABBREVIATIONS AND ACRONYMS

| | | |
|---|---|---|
| $^oC$ | : | Degree Celsius |
| $CH_4$ | : | Methane gas |
| $CO_2$ | : | Carbon IV oxide |
| CoP | : | Conference of Parties |
| CoV | : | Coefficient of Variance |
| EP | : | Early Planting Dates |
| FAO | : | Food and Agriculture Organization |
| GDP | : | Gross Domestic Product |
| GHGs | : | Greenhouse Gases |
| GWP | : | Global Warming Potential |
| IPCC | : | Intergovernmental Panel on Climate Change |
| ITCZ | : | Intertropical Convergence Zone |
| KARI | : | Kenya Agricultural Research Institute |
| KMD | : | Kenya Meteorological Department |
| LDC | : | Less developed countries |
| LP | : | Late Planting Dates |
| M.A.S.L | : | Metres Above Sea Level |
| Max. | : | Maximum Rainfall or Temperature |
| MDG | : | Millennium Development Goals |
| Min. | : | Minimum Rainfall or Temperature |
| MLR | : | Multinomial Logistic Regression |
| mm | : | Millimetre |
| NEMA | : | National Environmental Management Authority |
| NAPA | : | National Adaptation Programs of Action |
| SA | : | Sustainable Agriculture |
| SPSS | : | Statistical Package for Social Sciences |
| SSA | : | Sub-Saharan Africa |
| TAR | : | Third Assessment Report |
| UNFCCC | : | United Nations Framework Convention on Climate Change |

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# CHAPTER ONE

# INTRODUCTION

## 1.1 Background to the study;

Climate variability is the disparities in the means, totals, and other information such as coefficient of variance and standard deviation of climate variables for instance, temperature and rainfall observed for a shorter period, approximately 10-20 years (Luers & Moser, 2006). Climate variability may be brought about by variations in anthropogenic forces or internal natural mechanisms within the climate system (Selvaraju & Baas, 2007). Climate variability is a global problem that negatively affects people's livelihoods and weakens the systems of eradicating hunger and environmental sustainability (World Economic Forum, 2017). The devastating influence of climate variations on crops farming is a critical challenge that developing countries must deal with in this 21$^{st}$ century (IPCC, 2014). The climate change effect is great because crop output and productivity are highly reliant on climatic conditions that expose the sector to impacts of climate variability, further increasing adaptation costs (EU, 2014).

Globally, agriculture, especially crop farming, account for 24% of the entire world's gross output (Slater et al., 2007). Crop farming provides a source of livelihood to approximately 60% of sub Saharan Africa's labour force, contributes to about 17% of the Africa's total GDP, and also accounts for over 40% of its foreign income abroad (Harsch, 2015). The Kenyan economy greatly depends on rain-fed agriculture, mainly by cultivating crops susceptible to climate variabilities (Myers et al.,2017). In Kenya, climate variability has been associated with extensive negative effects on crop farming. This is because most small-scale farmers in Kenya depend entirely on rain-dependent agriculture. Indeed, above 75% of Kenya's population rely on crop agricultural activity for subsistence in food and livelihood income. This agricultural sector indeed contributes 60% to foreign exchange income and 26% to the GDP (Perret, 2006).

Statistics provided by the Meteorological Department of Kenya show that the climate of Nyandarua has been changing over the years. Likewise, the Ministry of Agriculture statistics reveal that crop output has also varied over time. The variation in crop output is perceived to be highly influenced by changes in climate and, to a lesser extent, other factors such as agronomical practices, seed varieties, market forces, diseases and pests, and loss of soil fertility (Mirzabaev, 2017).

Among the key negative impacts of climate variabilites and changes on crop farming is reduced crop yields and earnings (Fosu Mensah et al., 2012). According to Jobe et al.,(2020), adaptation strategies can increase the resilience of small scale farmers to climatic variability and, therefore, lower their vulnerability. However, costs and adaptations to climate variability are increasing due to changing agricultural systems in response to various determinants. These determinants include age and gender disparity, education and income level, land size and ownership, etc. The ability of small-scale farmers to adapt the impacts of climate variability is controlled by these factors (Lobel et al., 2012). These factors may encourage small scale farmers to respond and adjust effectively to climate variability and increase crop output (Mabe & Asase 2020).

On the other hand, these factors may also reduce farmers' adaptation capacity, making them more vulnerable. The anticipated rapid rate of climate variability requires the present testing of adaptive capacity. Climate variability is expected to present an intensified risk, especially to food security, particularly to the small holder farmers in Kenya because of their over-reliance on rain-dependent crop farming (WHO, 2018).

In Nyandarua County, the temperature variation trend has been on the rise since 1995, when the mean temperature was lowest at $21^0$C, followed by $21.5^0$C in 1998 and $23^0$C and $24^0$C in 2007 and 2013, respectively (Kiarie, 2016). 2016 was the hottest, with a mean temperature of $25^0$C, surpassing the record set by 2015 and 2014 earlier of $23^0$C and $24^0$C, respectively (Nyoro et al., 2004). Rainfall patterns and intensities have also been very unreliable and unpredictable. For example, the mean annual rainfall in Nyandarua County has varied for the last 20 years posting;- 1000mm in 1992, 1600mm in 1996, 700mm in 1998, 900mm in 2000, 600mm in 2004, 1200mm in 2010 and 900mm in 2013 (Jaetzold et al., 2015).

The agricultural output of some food crops in Nyandarua has also declined over time. Maize output, for example, has reduced from 54,941 tonnes in 2011 to 21,870 tonnes in 2016. The output of beans has also reduced from 7,000 tonnes in 2009 to 988 tonnes in 2016. Irish potato yield dropped from 1,143,955 tonnes in 2011 to 451,290 tonnes in 2016 (Devolution hub, 2018). The size of cultivated land has also been reduced from 80,331 ha in 2012 to 60,917 ha in 2016. These two occurrences have reduced the total agricultural earnings of the County from 8,943 million Ksh in 2012 to 4,961 million Ksh in 2016 (Devolution hub, 2018).

Nyandarua County is experiencing significant climate variability, impacting crop output and rainfall patterns, necessitating small scale farmers to adapt to these extremes.

## 1.2 Statement of the problem

Preliminary data from the Kenya Meteorological Department indicate an increasing temperature trend in Nyandarua County. Rainfall intensity and pattern have also changed, becoming very unreliable and unpredictable. Likewise, data provided by County government under the Ministry of agriculture reveals that the agricultural output of some crops has been declining. In addition, the size of cultivatable land in Nyandarua County has also been reduced from 80,331 hectares in 2012 to 60,917 hectares in 2016. Since the leading economic activity and major source of livelihood in Nyandarua County is crop farming, which is dependent on climatic factors, it was essential to study and understand the relationships between the climatic variables associated with rainfall amount and temperature, size of cultivatable land and crops output. The varying trends of these variables could mean reduced agricultural earnings, loss of livelihoods among small scale farmers and increased food insecurity among residents of Nyandarua County.

In response to these varying climatic factors and agricultural output variables, relevant planned adaptations could be the most appropriate responses to address climate variability risks on crop farming and ensure sustainable crop output (Smit et al., 1999). The adaptation strategies that farmers have employed have not been assessed, evaluated and documented. In addition, the existing adaptation strategies could have been seriously influenced by specific environmental and socio-economic factors (Singh et al., 2020). These factors may have contributed to either vulnerability or resilience to the negative effect of climate variability. This situation could mean that the extent in which a household involved in small-scale farming is influenced by climate variability largely depends on its vulnerability or resilience context comprising of socio economic features such as age, gender and marital status, size and ownership of land, level of education and income among the small scale farmers (Rakib & Matz, 2014).

The gap emanating from this relationship is that farmers develop their adaptations in a context of uncertainty brought about by climate variability. This indicates that farmers' adaptation strategies must be well guided through research (FAO, 2011). This informs the overall objective of the current study of assessing, evaluating, and documenting the adaptation practices established by small-scale farmers against climate variability's impact and examining the extent in which certain socio economic conditions and situations have influenced the adaptation strategies. This study adds new knowledge to the developing and evolving and limited empirical evidence about the relationship between climatic variables, crop farming output, effectiveness of adaptation strategies and their determinants.

Supported by these statements, it appears that numerous studies on climate changes and variability have focused on causes and mitigation measures, but there is lack of adequate research on climatic variability trends in Kenya, its impact on small-scale farmers' food crop production and adaptations. This study aimed to fill such gaps and provide more insights for the current and future studies.

## 1.3 Research questions

Three questions were used to address the gaps highlighted in the problem statement.

1. To what extent has climate variability influenced crop farming (output of maize crop and Irish potatoes) in Nyandarua?
2. What is the relationship between socio - economic factors of small-scale farmers and the choices of adaptation strategies for crop farming?
3. What is the effectiveness of the adaptation strategies taken up by small-scale farmers in response to the climate variability on improving the selected crop output?

## 1.4 General objective

The primary objective of the study was to assess, evaluate and document the adaptation strategies implemented by small-scale farmers to counteract the effects of climate variability on crop production in Nyandarua County.

## 1.5 Specific objectives

i. To assess the climate variability of mean annual rainfall and temperature from 1999 to 2019 and its impact on crop farming (maize and Irish potatoes output) in Nyandarua County.

ii. To analyse the influence of socio economic factors on small scale farmers' adaptation strategies on crop farming to climate variability.

iii. To evaluate the effectiveness of key adaptation strategies on crop farming to climate variability.

## 1.6 Hypotheses

The following three hypotheses were presented in this research as a basis for determining the existing relationships.

**$H_0$** Rainfall and Temperature variability does not significantly impact crop farming (maize and Irish potatoes output) in Nyandarua County.

**$H_0$** Socio-economic factors of gender, age, size and ownership of land, level of income and education do not significantly influence adaptation strategies adopted by small-scale farmers.

**$H_0$** Adaptation strategies by small scale farmers to climate variability do not significantly increase maize and Irish potato output.

## 1.7 Justification of the Study

Preliminary reviews indicate that the recently reduced crop yields and earnings in Nyandarua County had been linked with recent climate variability experienced in the region. In this region, most residents depend on crop agriculture for livelihood, with about 97% actually on rain-dependent crop farming (Kenga et al., 2005). The overreliance on climatic factors in crop farming may cause severe consequences on the output and productivity of certain food crops. This may be due to slight climatic changes like uncertainty in rainfall patterns, amount and variations in temperature changes (Mainardi, 2020).

Small scale farmers have responded to climate variability's impact in several ways. These adaptations need to be assessed, evaluated and documented through research. In order to promote planned adaptations that will enhance crop output and cope up with the influence of climate variability, there was a need to assess and analyse the influence of other factors affecting adaptation strategies arrived at by small-scale farmers. This would enhance food security, promote sustainable crop farming and improve the livelihoods sources of the farming rural communities (Assan et al., 2020).

The agricultural systems in Nyandarua County of maize and Irish potato crops farming were fundamental variables considered in determining the relationship between elements of climate variability, adaptation strategies, and influencing factors. Maize and Irish potatoes were the key dominant food crops in the entire County, so almost every household engaged in farming had either of the crops in their farms. These crops are mainly rain-dependent and are sold to earn a substantial income. Therefore, these crops' yield affects both food security and livelihoods. On the other hand, climate variability parameters are observed for fewer than 20 years, unlike climate change, which is observed for an extended period, usually decades. This justified the need to analyze the climatic data for a period between 15 and 20 years. Moreover, this is the period in which the County had registered remarkable variations in temperature, rainfall and crop output.

Nyandarua County, once a major producer of maize, wheat, and Irish potatoes, has experienced a significant reduction in output due to climate variability, leading to food insecurity. Small scale farmers are adapting to these changes, requiring effective strategies based on existing research.

## 1.8 Scope of the study and Limitations

Nyandarua County, located in agricultural ecological zones 3 and 4, is a crucial food basket in Kenya, with 97% of residents relying on rain-dependent crop farming. The dry region, particularly in Ndaragwa, is not part of the ASALs, allowing for easy comparisons between the different agro-ecological zones within the same county.

The choice of Maize and Irish potatoes was because they are crucial food crops in the county, generate substantial income for households, impacting food security and livelihoods through their rain-dependent yields. The study limited itself on the influence of rainfall and temperature on these two food crops in Nyandarua County. Because of data limitation, the study failed to consider other expounding climatic variables such as heat energy, crop management practices, agronomic factors such as the management of postharvest crop losses, diseases outbreak and pests etc. The study intended to use data on particular climate variables between 1999 and 2019. This period was considered to capture how climatic variables had influenced changes in crop output in Nyandarua. The study also confined itself in small scale crop farmers because they account for about 76.9% of the total population (Kenga et al., 2005). Large scale farming was not common in Nyandarua because the land had been extensively subdivided into small pieces.

The researcher anticipated the limitation of cost, time, language barrier, and lack of accurate records on crop production. The study's cost was high due to the extensive geographical study area. Traversing the whole study area took a considerably longer time. To address these limitations, the researcher intended to apply for a study leave and seek funding through scholarships once the proposal was approved. However a study leave was rejected by the employer and the researcher failed to secure any scholarship for the study. The language barrier was experienced in the circumstances when the respondents were unable to interpret the questionnaires due to low education levels. To address these limitations, the researcher used trained research assistant and community leaders conversant in the language of the community. The study encountered an issue in accessing accurate records on crop production for the study area, mainly relevant to the stipulated duration. However, records obtained from the Kenya Statistical Bureau (KEBS) and from the County department of agriculture offices provided reliable secondary crop output data to address the stated problem.

## 1.9 Definitions of key terms;

**-Adaptation** is the alteration in human or either natural structures to respond to expected or actual climatic change and variability or their effect (Parry et al., 2007). In the framework of this study, it is used to mean an agricultural arrangement to respond to climate variabilities extremes and its negative impact on selected crop yields.

**Climate Change;** – The IPCC (2014) defined it as a Long-standing changes in global weather patterns, explicitly related to variations in rainfall trends and extreme rise in temperature levels. Long-term climate change can be identified by persistent variations in its means or properties and typically lasting for decades.

**Climate Variability -** Climate variability has been defined as disparities in the means, totals, and much other information such as standard deviation and the coefficients of variance of climatic variables, for instance, rainfall variations and temperature changes observed for a shorter period of 10-20 years (Luers & Moser, 2016). In the context of this study, it refers to noted variations in climate contributed to by variations in recorded temperatures and rainfall due to usual internal mechanisms inside the climatic systems or changes in human environment and activities.

**Households -** A group of people staying together within the same compound, sharing specific roles and facilities such as cooking and investment (KDHS, 2013).

**Small scale farmers-** Types of farmers practising a combination of subsistence and commercial production of crops or livestock where family members offer the most labour force as the farm provides the primary source of income (FAO, 2011). The study refers the words to describe the peasant farmer who cultivates crops for subsistence use and, to some extent, sells the excess to earn income.

## 1.10 Organization of chapters

This thesis presents at least three publishable manuscripts themes organized into three chapters. It is guided by three objectives, forming the three critical chapters of results and analysis. The thesis is organized into eight chapters and opens up by presenting an introduction in chapter one which sets up the background information of the thesis and outlines the hypothesis, objectives and research questions. Chapter two presents the literature review and theoretical framework: The Ricardian theoretical model is adopted to develop the conceptual framework: Research gaps and the expected knowledge contribution are also presented in this chapter. It is then followed by chapter three, which presents the study area, maps and other descriptions. Chapter four presents the quantitative and qualitative research methodology and inferential and descriptive statistics. Chapter five presents the analysis output of the results, interpretation, explanation and discussion of the study's findings based on the initial goal of determining how Nyandarua County's crop farming specifically, the production of maize and Irish potatoes is impacted by climate variability in mean annual rainfall and temperature.

Chapter six, on the other hand, presents the findings of the $2^{nd}$ objective, which is the assessment of the relationships between the socio-economic factors and the adaptation strategies employed by small-scale farmers as mitigation plans against the incidence of climate variations on crop farming agriculture. Chapter seven evaluates the effectiveness of adaptation strategies employed by small-scale farmers against the effects of climates variability on crop farming under the third objective. Lastly, chapter eight presents the contributions summary and results discussion from all the three chapters and finally draws out conclusions and recommendations.

# CHAPTER TWO

# LITERATURE REVIEW;

## 2.1 Introduction

The chapter reviews what other researchers have done that is important to climate variability, its impact on crop farming and adaptations. The literature review enabled the researcher to develop new knowledge and skills from the study gaps. A review of the Ricardian theoretical model was done to develop an appropriate conceptual framework to describe the relationship and inter linkages between and within the independent factors and dependent variables.

## 2.2 An outline of climate variability and its impact on crop farming;

Human activities contributing to greenhouse gases have increased for several decades, especially in the most developed and developing countries (McNamara et al. 2020). These anthropogenic activities have increased greenhouse gas emissions into the atmosphere. These greenhouse gases had increased the atmospheric temperature by $0.4^0$c to $0.7^0$c towards the end of the $20^{th}$ century; (IPCC, 2011). This global climatic variability has affected crop farming in several ways. Studies have shown that an increase in temperature may reduce crop duration by fastening maturity and ripening of some crops (Georgis K. 2010).

Research has shown that an increase in mean temperature beyond a threshold may cause a decrease in agricultural output (Smit et al., 2000). Further studies have revealed that changes in the lowest least temperature is more significant than a change in the recorded maximum temperature (Ojwang et al, 2010). Regarding these effects, a study by Pathak et al. (2012) in India has revealed that rice harvests declined by 10.0% for each $1^0$c increase in the growing spell temperatures above $32^0$c. Similarly, rice productivity in Punjab (India) decreased significantly by 5.5%, 7.40% and 25.10%, with a rise in temperatures of $1^0$c, $2^0$c and $3^0$c, respectively, in 2003 (Aggarwal et al., 2009). Referring to Ahmed et al., (2016), the precipitation and rainfall patterns tend to change when the atmosphere is heated due to accumulating temperatures from global warming. Some areas become wetter while others become drier. This rainfall variation may also negatively affect crop farming (Howden, 2012).

In Africa, the average rainfall has portrayed a decreasing trend of 7mm per year since 2000 (WHO, 2018). Rain reduction is more than ten times that of the Latin and Caribbean America. The unreliability and decrease in rainfall pose a weighty threat to issues of food security and livelihood in Africa, for example where nearly 90% of crops agriculture is dependent on rainfall (WHO, 2018). A study conducted in Africa by IPCC (2011) showed that 25-42 % of agricultural habitat in Africa could varnish by the year 2020, causing a reduction in food crops. In Nyandarua County, Kenya, climate variability was likely to reduce cereal production by about 16 per cent, while 11 per cent of cultivatable land was likely to be lost within five years (GoK, 2010). Therefore, farming communities, agricultural and environmental experts and policymakers must develop comprehensive adaptation measures to address the negative impacts and influences of climate variability and its effect on agriculture (Ngigi, 2017).

## 2.3 Climate variability in Kenya and its impact on crop farming

Unique climate patterns have been witnessed in Kenya, with El Niño of 1997 and 1998 and La Niña of 1999 and 2000 incidents being the most far-reaching in the last two decades (Downing & Watkiss, 2009). Kenya has broadly experienced increasing mean temperatures since 1960, averaging at the rate of 0.21°C in one decade, representing a general warming trend over time. Likewise, yearly peak rainfall from 2014 showed a dropping trend compared to the long rainfall season recorded from 1960 (GOK, 2018).

Uncertainties in critical climatic variables are a pertinent discourse in several parts of the world and Kenya in particular regarding their implication on food security and source of livelihood (Omoke et al., 2014). Various reports on the climate situation in Kenya demonstrate the increasing unpredictability of rainfall patterns. Mutunga et al. (2017) observed similarities between smallholder farmer's perceptions and the meteorological indicators of the climatic conditions in Kenya. The Kenya meteorological department had also indicated a heating trend in the temperatures between 1961 and 2019. Oluoko-Odingo (2011) noted that an overall general rise in maximum and minimum temperatures of between 0.2–1.3 °C and 0.7–2.0 °C had been recorded between 2000 and 2009. The period recorded the warmest temperature readings. The challenges affecting small scale and small holder farmers in Kenya are related to variation in the output of their crops. Climate variability, as manifested through rainfall unreliability and prolonged drought, is among the top possible cause of reduced crop output (Mikalitsa, 2010). Concerning the significant crop performances in Kenya, maize has been the most negatively affected crop in the last two decades (Wambua et al., 2018).

Kenya's agricultural sector, especially crop farming, has been the mainstay of the entire country's economy since independence and, therefore, a major source of livelihood for most Kenyans'. Kenya's agriculture and more so crop farming is most susceptible to the effect of climate variability because it depends mainly on rainfall and the country's low capacities to adapt to climate variability effect. Due to climatic variability, rainfall intensity and distribution have become inadequate and very unreliable. Ojwang' et al., (2010) detected that maize harvested in Kenya had been decreasing at an alarming rate over the past five years. Increasing temperature and changing rainfall patterns were expected to continue in the 21$^{st}$ century. This trend was likely to affect the yields and output of major crops in the country, contributing to a reduced agricultural crop production, earnings and food security and livelihood in Kenya (GOK, 2018).

Kenya's maize cereal production on a small scale contributes to about 75% of the total maize output production, while large-scale maize output and production contributes to 25% (Olwande, 2012). New maize varieties respond to different types of agro ecological zones. For instance, the varieties of highland maize comprise the H625, H626 and H627. These maize varieties are appropriate for moderate to high altitude areas ranging from 1,500-2,100m above sea level, with a maximum temperature of $28^0$C and a minimum of $8^0$C. These varieties of maize require rainfall ranging between 800-1,500mm annually. The highland regions of Kenya like Nyandarua, Nakuru, Transzoia, Uasin Gishu, Kisii, Narok and Kericho are favoured by the highland maize variety (Schroeder et al., 2013 and The Kenya Seed Company, 2013).

The Irish potato is mainly cultivated in the cool and moderate-high altitude regions with well-distributed rainfall. The optimum temperature range is from $16^0$c to $20^o$c. Temperatures above $32^o$c result in poor tuber initiation. The Irish potato crop is susceptible to frost. Therefore, it is essential to protect it by avoiding cropping during the extremely cold period. The effect of frost destruction on the Irish potato is high between June and July in the central part of the country. To maturity, the Irish potato requires a minimum of 400mm of well-distributed rain water. The most appropriate altitude is between 1,500 metres and 2,450 metres above the sea level. The long rain planting is done in October and November, so harvesting is done in January and February. The short rain potato is planted in the month of March and harvested in the months of July and August (Schroeder et al., 2013).

## 2.4 Adaptations to Climate Variability in Crop Farming

Climate variability is a major significant determinant in crop farming (Diiro et al., 2016). The output of rain-dependent crops often declines due to regional and temporal variability of climate (Simotwo et al., 2018). Crop farming provides humanity with essential food and therefore promotes food security. One of the 13 Sustainable Development Goals (SDGs) of the United Nations, which was formally accepted in September 2015 and is expected to be accomplished within the next 15 years, addresses the need to deal with climate variability (Malik, 2010). The importance of strengthening adaptive capability and resistance to climatic variability and other natural disasters was highlighted by this goal. Regarding adaptation in agriculture, the 13$^{th}$ goal was linked to the second objective of eliminating hunger, achieving 100 per cent improved nutrition through food security and promoting sustainable agriculture (UNFCCC 2018). The implementation of resilient agricultural farming practices that boost crop productivity, preserve natural ecosystems and strengthen individual and collective capacity for adjustment and adaptation to the effects climate variability and extreme weather conditions, and gradually improve land and soil quality are all necessary to achieve this goal. Sustainable food crop production structures are also necessary. Therefore, the need to maintain or improve crop output amidst the regional and temporal variability of climate is clearly expressed and agreed upon internationally (Mutunga et al., 2017).

Adaptations refer to social, economic or ecological adjustments in response to the actual or either expected climatic factors and their impacts or effects (Deressa et al., 2010). It also denotes the changes and deviations in practices, specific processes and certain structures to regulate possible damages from climate change and variability opportunities. In susceptibility assessments, the magnitude to which natural ecosystems, sustainable development and food supplies are vulnerable depends on exposure extent to variations in climatic variables and the ability and possibility of the affected farming structures to adapt (Wambua et al., 2018). In this respect, adaptation in crop farming is a significant policy in response to the effects of climate variability. In this case, there is a need to develop, assess and apply some planned adaptation techniques, measures and strategies to help manage the exposure to climate variability, especially in agriculture. Adaptation strategies vary according to who undertakes them, the systems of farming in which they tend happen, the climatic conditions that prompt them, and their forms, functions, timing and effects (IPCC, 2007). This study focuses on adaptation measures deliberately undertaken by small scale farmers involved in crop farming in a particular region of the country that is food sufficient where crops are rain-dependent.

### 2.4.1 Types and forms of adaptations based on UNFCCC 2018 classification

Adaptations come in various forms and ways of classifying them. These types of adaptations have been generally differentiated and classified according to several attributes (Bryant et al., 2000; Leary, 1999; Feenstra et al., 2015). The frequently used classification patterns are based on features such as intent to or purposefulness for, action of agents, timing and historical scopes. The classification of adaptations based on intent, timing, agents, and temporal scope is crucial for understanding climate change and variability. Spontaneous and autonomous adaptations occur in a reactive, immediate or delayed response, while planned adaptations are policy decisions based on the expected change of situations. Two forms of adaptations are proactive or anticipatory adaptations, which involve long-term decisions and improving farmers' ability to cope up with future climate variability scenarios, and reactive adaptations, which are immediate responses to climatic events. Public and private adaptations are also important, with public adaptations initiated by governments and private adaptations by individual families or households. Long-term and short-term adaptations are also important, with some methods being more appropriate in the short term.

## 2.5 An overview of climate variability adaptations in crop farming

Adaptation and mitigation measures are common reactions to counter climate variability effects (Doidge, 2020). Rosegrant (2008) suggested that using effective adaptation techniques could lessen the risks that climate variability poses to human and ecological systems. Gbetibouo (2010) previously contended that climate variability and change are generally unfavourable to the agricultural crop-growing industry in the absence of adaptations. Several studies show that small-scale farmers adapt to climatic variability in a variety of ways to counteract its detrimental effects to the farming activities. (Hassan and Nhemachena, (2008); Fosu Mensah et al., 2012; Apata et al., 2009; Rosegrant 2008; Deressa et al., 2010 and Gbetibouo, 2010). Pachauri et al. (2015) further found that the adaptation approaches used by small-holder farmers of South Africa ranged from planting drought-resistant varieties to diversifying livelihoods such as getting off-farm work or starting businesses and forming networks such as cooperatives and community farming projects. The current study anticipated to observe some crop related adaptations in the area that may not have improved crop yields as expected.

A study by Mburu (2013) in dry region of Yatta District now referred to as Yatta constituency in Machakos County revealed that small scale farmers engage in various adaptation measures to climate variability, such as planting drought-resistant crops, rainwater harvesting, charcoal burning, and sand harvesting etc. The Chi-square technique results indicated that education levels significantly influenced these adaptation strategies. This study focused on dry land agriculture, where farmers do not depend so much on rain-fed agriculture. It failed to examine determinants of adaptation strategies in regions of food sufficiency like Nyandarua County, which mainly depend on rain-fed agriculture. The current study sealed this gap and allowed inter-regional comparison regarding climate variability and adaptation strategies.

A more recent study by Mwangi et al. (2020) has established that staggering planting dates is an emerging adaptation strategy where small scale farmers isolate the farms by planting some parts of the farm before the rain start and others after the immediate onset of rain. This practice helps mitigate the risk of seed loss and the need to reduce the cost of replanting the whole farm again when crops fail to germinate or develop.

### 2.5.1 Crops diversification

Crop diversification may be defined as growing more than one food crop in a specific area. Crop diversification can be promoted by introducing a new crop variety different from the original or a complete new cropping system. Therefore, agricultural diversification means farmers consider other non-farming activities like animal husbandry and livestock keeping as a source of livelihood or changing the cropping pattern. This practice enables small scale farmers to increase crop production and output, which helps generate higher levels of income and livelihoods. Agronomists have described the changing of a cropping pattern as a method of diversification between non-food and food crops, horticulture and conventional crops, low-value crops and high-value crops (Otiso et al., 2022). The emergence of the Golden revolution (1991-2003) saw the method of diversification flourishing very fast across the globe. Crop farming diversification is an approach for promoting the well-being of low-income rural small scale farmers' households. Its positive contribution includes improving food security, generating more employment opportunities and biodiversity conservation (Otiso et al., 2022). Mugivane F.I. (2006) highlighted the common feature of food insecurity among women in Kenya, highlighting their significant role in addressing this issue.

Recently, new prospects for crop diversification have come up, especially for commercial farmers. The crop diversification method has enabled better flexibility among the farmers, allowing them to leverage on opportunities brought about by the changing regional and foreign market conditions. Horizontal diversification enables the farmers to produce different crops, while vertical diversification enables them to engage in different value addition activities. This particular adaptation strategy has promoted the incidence of nutritional balance of people's healthy diet, improving their health status and increasing their capacity to do work. However, Sub-Saharan Africa's farmers have been unsuccessful in securing the benefits of crop diversification. This is because of inadequate resources and the lack of necessary information and skills to undertake proper crop diversification. Studies have shown that very few farming units in Kenya can generate sustainable income by adopting technology for crop yield and increasing or improving the marketing and processing practices. Likewise, many farming units or regions often focus on planting only a few crops yearly instead of horizontal production while varying the regions.

#### 2.5.1.1 Benefits of Crop Diversification

The advantages of adopting crop diversification are summarised below

- Harvesting multiple crops from a small farm increases production and consequently earning a substantial income.
- Crops diversification improves soil fertility in terms of nutrients and to control pests and diseases.
- It helps farmers not to lose all of their resources, especially when the weather does not favour crop production, reducing the risk factor.
- Effective adaptation through crop diversification provides additional employment opportunities in rural and remote areas.

In Kenya, the Irish potato crop is an excellent crop for diversification. The probable reason for this hypothesis is that many households in the rural areas especially in central region depend on the crop as a primary or secondary food source. The Irish potato has a shorter vegetative cycle and is highly flexible because it can be planted and harvested within 100 days. Irish potato is highly productive compared to maize, wheat, and rice. Indeed it produces more yields per unit area and time. Regarding nutritional value, Irish potatoes are rich in Vitamin C, Calcium and Protein with a perfect balance of amino acids. The pronounced adaptability of the Irish potato to almost any altitude and various climates, including the dry conditions, is another excellent aspect of the crop. The crop is already being cultivated in the form of wide varieties as primary and off-season crops in different parts of Kenya. The Irish potato can be intercropped with many other foods and cash crops in a rotational manner, such as maize intercropped with Irish Potatoes simultaneously in the same piece of land. The Irish potato requires less fuel, a short cooking time, and a high possibility of value addition, e.g. chips and crisps. These reasons make the potato popular with both rural and urban consumers. Furthermore, the Irish potato crop generates significant employment opportunities in production, marketing and processing levels. More than 1000 farmers in Nyandarua County have embraced diversification of high-value crops like new Irish potato varieties, hybrid maize varieties, grafted avocados, tissue culture bananas, French beans and cowpeas to realize economic stability instead of relying solely on maize.

### 2.5.2 Drought-resistant crop varieties

Drought resistance or tolerance has been defined recently as the ability of a crop to maintain its average biomass production during extreme drought conditions (Ngeno K. and Bebe O.B., 2013). A crop tolerates drought by responding to specific conditions, e.g. minimizing water loss and maximizing water uptake. Staple food crops like sorghum, cassava, millet, sweet potatoes and groundnuts are naturally more drought-resistant than maize. (Speranza, C.I., 2010).

#### 2.5.2.1 Drought resistant Maize varieties

Planting new drought-resistant and fast-maturing maize varieties is an adaptation strategy that the smallholder farmers of Kenya are quickly adopting. Like many other small scale farmers spread across the agricultural counties of Kenya, small scale farmers in Nyandarua County are gazing at a huge crop loss. Continued dry climatic spells have endangered the food security and livelihoods of many rural families in Kenya who depend exclusively on rain for their crop farming. In this case, most small scale farmers naturally plant farm maize seeds, which lack the characteristics to endure harsher weather conditions such as extreme heat and or water stress (Rashid, 1996). Such conditions hardly make farmers harvest the best maize output from their lands. A study by Mutunga (2017) in Kitui concerning the smallholder farmers' perceptions and applied adaptations to climatic change and variability established that 22% of the respondents planted drought-resistant and tolerant crops like ground nuts, millet, cassava, and sorghum. The smart agriculture project in Nyandarua has been assisting small scale farmers in choosing the suitable maize variety for short rains. In 2019, it was noted that the supply of maize flour was less across the country due to a severe shortage of maize grain, and the demand was remarkably high due to most Kenyan families adopting maize as the staple food crop.

During the famine, the imported maize did not reach many Kenyans in rural areas. The Northern part of Kenya is one of the few regions that depend on relief food. Because of this reason, many households in other parts of the country do not have an alternative but to depend on what they cultivate on their farms for their food security. Therefore, small scale farmers in Nyandarua County require taking advantage of the short rains to grow more drought-tolerant varieties that take a short time to mature. Table 2.1 below presents some drought-resistant and fast-maturing maize varieties favourable in different altitudes in the short rain season. The Kenya seed corporation ltd has developed a variety of drought-resistant and fast-maturing maize varieties with high yield per acreage. Some of these varieties are highlighted in the table below:

**Table 2.1: Hybrid Maize Seed Varieties Resistant To Climate Extremes In Kenya**

| Variety | Condition | Altitude (m.a.s.l) | Maturity | Yield (x 90KG/Acre) | Attributes |
|---|---|---|---|---|---|
| H614D | Highland Maize | 1500-2800 | 160-210 Days | 38 Bags | Sweet tasting variety, high density, long storage period and resistant grey leaf spot and blight. |
| H628 | Highland Maize | 1500-2800 | 150-180 Days | 46 Bags | Highland variety with heavy white grains. It has high output and is resistant to blight and GLS flint. |
| H513 | Medium Maturity | 800-1700 | 110-130 Days | 38 Bags | Medium variety, delightful tasting, and good stand ability. |
| H516 | Medium Maturity | 800-1700 | 120-150 Days | 46 Bags | Medium to highland variety and resistant to blight rust and lodging |
| H517 | Medium Maturity | 800-1700 | 120-150 Days | 30 Bags | Tolerant to foliar diseases incidence and pests infestation.<br>Has better husk cover, tolerant to cob rot and maize streak virus (MSV) |
| DH01 | Drought Resistant | 800-1500 | 70 Days | 15 Bags | Early and Stay Green<br>Tolerant to blight and rust |
| DHO2 | Drought Resistant | 800-1500 | 70-100 Days | 16 Bags | Suitable for arid and semi-arid areas. Early tolerant to moisture stress |
| DHO4 | Drought Resistant | 800-1500 | 75-100 Days | 24 Bags | Short drought tolerance<br>Good husk cover and stand ability |
| DH08 | Drought Resistant | 800-1500 | 100-120 Days | 28 Bags | A type of field corn with high soft starch content. Good stand ability and tolerant to ear rots |

Source: Kenya Seed Company limited catalogue 2020

### 2.5.2.2 Drought Resistant Irish Potatoes Varieties

According to the Potato National Council of Kenya, wide modern varieties of Irish potatoes in Nyandarua County are drought-sensitive. These varieties include Annet, which requires a medium to high altitude of between 1,300-2,000 m.a.s.l. It has a short maturity period of (≤ 3 months) with a medium output yield of (30-35 tons/ha). Asante, requires a medium maturity period of (3-4 months) with a medium to high output yield of (35-45 tons/ha). It is best at a high altitude of ≥2,300 m.a.s.l. It is resistant to late blight disease though it can be affected by late-season infections.

Desiree requires a high altitude of 1,800-2,600 m.a.s.l. The variety has an early to medium maturity period of (2.5-3.5 months) with a medium to high output yield of (35-40 tons/ha). Desiree is an upright medium to tall variety (about 0.7 meters in height from the ground). The dark green medium-sized leaves and strong stems offer the plants stability. Its flowers are light pink and occur scarcely. Desiree is largely affected by Potato Virus Y (PVY) disease.

Kenya Baraka requires a high altitude of 1,600-2,700 m.a.s.l. it has a medium maturity period of (3 months) with a medium to high output yield of (30-40 tons/ha). It has a long tuber dormancy of 4.5 months, making it a highly suitable drought-resistant crop. Kenya Baraka is a tall vertical variety plant (about one meter of height) with broad green leaves and strong stems. Its white flowers moderately appear. The variety is resistant to diseases such as Late blight.

Shangi potato variety requires an estimated altitude of 1500 m.a.s.l. it has an early maturity period of (≤3 Months) with a medium output yield of (30-40 tons/ha). It has a short tuber dormancy of (≤1 Month), making it a highly suitable drought-resistant crop for faster adjustment of planting dates. Shangi potato variety is a medium-tall semi-vertical, slightly below 1 metres height, with light green broad leaves and moderately strong stems. Their pink flower profusely comes out. Shangi potato variety is moderately vulnerable to the disease of late blight. Other potato varieties include Kenya Karibu, Kenya Mpya, Kenya Sifa, Kenya Mavuno, Mayan Gold, Purple Gold, Sherekea, Tigoni, and Dutch Robijn.

### 2.5.3 Adjusting planting dates

The advantage of early planting date for maize crops could yield high production, especially when accurate data on the onset of rain is available. For maize, the planting date window, which expands the growing season while considering other favourable conditions at critical crop growth stages, has been one of the main issues to be well-thought-out for high-yielding crop production. Ngetich et al. (2011), while studying the effects of planting dates in central Kenya, observed no significant effect on maize yield during the long rains season of 2010, concluding that rainfall patterns and amounts caused this. Therefore, to optimize yield under variable climatic conditions, planting at the correct time to fit with partial crop maturity length and the growing season is essential (Shrestha, 2018).

An evaluation of the best times to plant maize in order to adjust to rainfall unpredictability and improve food security in Ol-Joro-Orok, a sub County in Nyandarua County Kenya, was carried out by Onyango (2018). Comparative analysis between the planting dates was done using air-dried grain harvested at physiological maturity separated from the cobs. In the long rains of 2012, the yield difference between the two planting dates was 8.7%, while in the 2013 spots of rain, it was 23.6%. The differences in yields between the planting dates in 2012 were not significant, but they varied significantly at $p < 0.05$ during the 2013 showers. Long-term models have also revealed that lengthier maturity crop hybrids lose their output faster than short-maturity span hybrids with significant planting delays. In Kenya, about 27% increase in the yield and output of planted dry maize was recorded during the short rain season of the year 2009. However, the wet planting effect was insignificant (Mutunga et al., 2017). Ngetich et al. (2011), for example, showed that comparative to late planting; dry cultivation of maize increased the production by 53% at significance levels of $p \geq 0.05$-during the 2009 long showers of the rain season, followed by showery planting that contributed to about 19% increase in crop yield in central Kenya. In the central highlands of Kenya, Ngetich et al. (2011) evaluated the consequences of early planting dates (EP) and late planting dates (LP) as treatments on the performance of maize (DK8031 variety). The study focused on the effects of planting dates on maize yield and output under rain-fed conditions.

The crop treatments were simulated thrice in a Complete Randomized Block Design, consisting of two planting dates, the last one week after the first. During the prolonged rain of the 2018 season, early planting was done on 18th April 2018, while the late planting treatments were on 28th April 2018. Early and late planting during the prolonged rain 2018 was done on 2nd May 2018 and 14th May 2018, respectively. Grain maize crop yields were measured at maturity and expressed in Kg/ha. Findings from the variance analysis carried out indicated that the difference of days between early and late planting during the LR2017 season was 10, while in LR2018 was 12 days. The germination of maize in early planting was over 90%, while there was very poor germination in late planting crops, especially in the LR2018 season. The output yields of maize were significantly affected by seasons ($P \leq 0.05$), with the harvests of the late-planted crop in 2018 being the lowest. While maize yields in 2018 were lower than in 2017, late planting remarkably reduced the establishment and yields of maize.

According to Sangoi et al. (1998), the planting date contributes to the development, growth and output of maize crops. The most appropriate planting dates have become of great importance for increased crop production. Optimum planting dates well controls the foundations of plant growth and disease and pest outbreaks. Many studies have shown that different crop varieties like maize and Irish potatoes respond and react differently to various planting dates in a calendar. Late or early planting dates of maize may result in some morphological, biological, biochemical and structural changes in plants. These changes affect many plants' growth and development especially in maize and Irish potato, resulting in a drastic decline in crop yields (Ke, F., & Ma, X. (2021). The growth and development of maize involve many biochemical reactions, which are delicate alterations in weather parameters due to variations in planting dates. Late planting affects elements of physiological growth, photosynthesis and dry matter production as a result of a decrease in the accumulative capture of photosynthetically active radiation (PAR). Delayed planting dates may lead to increased non-structural carbohydrates concentration in the maize stems due to low temperatures, limiting the rate of photosynthesis and seed growth. Starting a maize farm within the early planting season is better for market and demand reasons. The optimum planting date for maize in Nyandarua is between 15th March and 15th May, although planting could be done as soon as rainfall becomes steady.

Irish potatoes require a 2 to 3 months period after planting to mature. The indicator that harvesting of Irish potato should be done is when the foliage turns brown. Harvesting of the potato is done well when the soil is dry. Potatoes should be planted in many parts of Kenya in February or early March. If the Irish potato is planted too early, it can lead to the top becoming frozen off by frost. There are three cycles for adjusting the planting dates of Irish potatoes: early potatoes can be planted as early as mid-March, and early potatoes should be planted a few weeks later. In order to yield a healthy crop, main crop potatoes must remain in the ground a little bit longer after planting, which typically occurs in April. Due to variation in climate, there has been a general shift in the planting of Irish potatoes to early June. Irish potatoes planted early may need approximately 100 days to mature, while those planted late may need about 120 days to grow and mature. Therefore early planting, i.e. in May and June, will give a higher output before December in Nyandarua.

In conclusion, the adversative effects of deferred planting times can be lessened by predicting the optimal planting dates based on proper and accurate crop modelling experiments (Ahmed, 2020).

### 2.5.4 Income diversification

Income diversification was defined as the addition of income sources or drawings earnings from many sources rather than relying on one job activity for income. Ellis (1998) noted that most households of small-scale farmers avoid relying on few sources of income for a longer period of time due to environmental risks. According to recent research, rural small-scale farmers in Kenya's semi-arid and dry regions can effectively manage the risk of drought by implementing the approach of income diversification (Watete et al., 2016).

According to a study conducted in China by Jinhong et al. (2016), income diversification can help rural communities become more resilient to climate variability, lessen the negative effects of drought, and increase the stability of their revenue sources. Even though farmers' incomes often make up a bigger portion of the incomes in rural communities, there are a number of reasons why off-farm income diversification tactics may occur, including insecurity brought on by the negative climate variability's impacts (Delgado et al., 1997). According to certain research, farmers that experience low income levels tend to concentrate mostly on subsistence farming (Reardon et al., 1994). Likewise, income diversification increases with increased levels of agricultural commercialization. Diversification of income through off-farm and on-farm economic activities among the small-holder farmers in the Sub-Saharan Africa mainly depends on risk mitigation strategies, among other detrimental climatic stresses (Bellon et al., 2014). According to Adger (1999), when a single household describes it's self as having undertaken multiple income sources over time, it is typically an indicator of sensitivity and vulnerability to societal problems, including climatic and other ecological and environmental variables. Income Diversification is a valuable strategy in dealing with disaster risks and social welfare improvement but also provides new insights for advanced research on resilience, vulnerability and adaptive ability of small scale countryside social systems. Generally, deprived rural communities try to find livelihoods sources outside the farming sectors to supplement the periodic incomes from agricultural activities. Income diversification should help to moderate vulnerability by levelling income and distributing income risks across numerous activities. The household-based undertakings in the non-farming activities to get income could be one of the adaptation strategies that are not crop-related and can be used to eliminate poverty and increase their adaptive capacity to other adaptation strategies.

Engaging in non-farm income-generating activities has offered more employment opportunities in the rural areas, slowed the rural to urban migration, and contributed to a more fair distribution of income (Gordon, 2001). The empirical analysis in Kenya shows that the local disparity in income diversification does not trail any particular patterns with pull and push determinants occurring concurrently within and between regions. In this regard, income diversification policies must be custom-made to meet the development requirements of specific regions. To a greater extent, income diversification is significantly linked with asset households' endowment, nearness to rural towns, population factors, migration trends and sensitivity to food security (Suvedi and Kaplowitz, 2016). Diversification of income sources among the smallholder farmers in the county of Nyandarua was one of the strategies of adapting and adjusting to the negative impacts and influences of climatic factors variability on crop farming. The gap is that the adaptation strategies have not been thoroughly evaluated to establish its effectiveness in improving crop yields.

## 2.6 Socio-economic determinants to adaptations in crop farming

African nations are severely affected due to inadequate skills in climate variability impact management, weak institutional capability, high dependence on rain-fed crop farming and limited financial resources (Rockstrom, 2010). The most significant proportion of the human population depends on subsistence agriculture, which exposes them to more levels of vulnerable conditions (IFPRI, 2004). According to FAO (2012), many challenges small scale farmers encounter in adapting to climate variability are related to poverty. In this case, farmers divert their little income from the farm towards acquiring primary necessities like food and medical care instead of allocating them into crop farming adaptation strategies. Studies by Reenberg and Nielsen (2010) suggest that monetary obstacles are significant barriers which limit the execution and implementation of proper adaptation measures and strategies by crop farmers in Africa. According to Adger et al., (2007), the effective implementation of adaptation strategies is hampered by the lack of knowledge regarding climate variability. One of Africa's biggest obstacles to climate adaptation has also been identified as the absence of appropriate technology solutions to address the detrimental consequences of climate variability (Nielsen et al., 2010).

According to IPCC (2014) report, vulnerability to climate variability effects among small-scale farmers is directly related to poverty. This makes the level and source of income of the small scale-farmer a good indicator of their capacity to control and adjust to instances of climate fluctuation. IPCC, 2014 further stated that low education levels could strongly inhibit the community and society's ability to apply and implement the adaptation ideas. This is by restricting the variety of possible reactions and interventions that can be applied. Hence, a community and society level of education, knowledge, awareness and capability to adapt and adjust to crop farming technologies are significant determinants of adaptive solid capacity.

Antwi-Agyei et al. (2017), highlighted that in many cases, adaptation methods and choices are restricted by the shortage of financial resources, low education levels, small size and unstable ownership of land, old and young age and gender of the small scale farmers. Ngigi's (2009) studies indicate that the possibility of having numerous adaptation options which produce positive results is not a guarantee of good returns. This is because adoption of these strategies can be very slow. Therefore, the study suggests that it is essential to understand the factors influencing the adaptations to climate variability in a low spatial location to speed up and strengthen the uptake of the most effective adaptation strategies.

## 2.7 Factors influencing adaptation to climate variability in Africa

Studies conducted by Nhemachena and Hassan (2008) observed that adaptation plans by small holder farmers in south African countries was based on improved cross sectional data obtained from Zimbabwe, Zambia and South Africa. Using Multivariate Logistic Model, they found that awareness of climate variability and easier access to agricultural extension and frontline services were the main determinants of farmers' adaptation consideration to climate variability effects. The study also revealed that single cropping is one of the Africa's crop farming practices that is most vulnerable and susceptible to the consequence of climate variability. In addition, the level of technology and availability of elements of production (capital, land and labour) were established as essential factors in helping small scale farmers in informed adapting to effect of climate variability in Africa. This study assessed the influence of high technology of using heavy machines supported by agriculture, which were not considered in the Nyandarua area because small scale farmers neither used heavily mechanized farming systems nor electrified operations. However, the study reveals similarities in determinants such as the farm size, gender and age and level of education which the current study seeks to assess. It will be essential to compare the results between these two study areas.

Deressa et al. (2010), when using the Heckman regression model in the Nile basin of Ethiopia, found that the elderly farmers were more experienced in farming because they were extensively exposed to present and past varying climatic conditions. Their studies concluded that age was a direct contributor to the adaptation strategy employed by farmers. Contrary findings were found in Hassan and Nhemachena's (2008) studies for determinants of adjusting to climate variability in African continent, where age was found to have insignificantly influenced farmers' adaptation to the consequences of climate variability. However, it can be argued that what matters is the farming experience and not the farmer's age when it comes to the issue of adaptation. This is because extended farming experience escalates the chances of farmers adapting and adjusting to climate variability better. The findings also revealed that levels of farmer’s education positively affected adaptation, while the farm size negatively influenced adaptation strategies.

Mudzonga's 2012 study in Zimbabwe found that education significantly impacts farmers' adaptation to climate variability, with shifting education levels increasing the likelihood of familiarizing farmers with climate change. The study's results further concurred with another similar study done in southeast Nigeria which found out those farmers having large farms adapted better than farmers with smaller farms (Ozor et al., 2012). Large farms generally involve a high investment, which considerably should initiate better adaptation practices to contribute to reasonable returns. The gap between these studies is based on the methodologies used. Mudzonga (2012) used the Multivariate Logistic Model, while Ozor et al. (2012) used the Probit regression model. The current study used the Correlation and Multinomial regression model unlike many other past similar studies. It was envisaged that the results of the current study were more accurate and meaningful due application of both correlational and association techniques, respectively.

## 2.8 Factors influencing adaptation to climate variability in Kenya;

Numerous research (Mutunga et al. 2020, Msafiri et al. 2021, etc.) have been done on the variables determining adaptations to the unpopular climate variability's impacts in Kenya. The specific environmental and socio economic factors that affect adaptation techniques in a high yield or food basket agricultural zone are, however, rarely discussed in studies. A study on Kenyan farmers' use of adaptation tactics to climate variability and its effects on crop farming were undertaken by Gebre et al. in 2002. They found that farmers were more likely to use a range of crop-related climate change adaptation strategies if they were younger and more educated. The number of adaptation methods implemented was positively correlated with the following factors: farm income, education levels, family and land size, male farmers, and information availability. Knowing what influences of the primary adaptive strategies will provide understanding on the many factors that work well in leveraging crop production amid the extreme phenomena of climate variability in order to promote sustainable livelihoods issues and food security. The outcomes of this study however contradicted the results of another study done by Ngigi (2017) in her PhD theses entitled “Managing risk under climate change in rural Kenya” which indicated that a more considerable proportion of women were found to embrace crop-related adaptation strategies while men employed agroforestry and livestock-related adaptation strategies. By applying a Chi-square and correlation coefficient to a sample data of 360 households, the study concluded that there was a need to consider gender representation among small scale farmers to successfully support women's and men's specific abilities to adapt effectively to climate variability and uplift their livelihoods against the changing climate. Regarding farming experiences, results indicated that the many years a farmer had engaged in crops farming was insignificant to influence the adoption of micro and macro climate variability adaptations.

In conclusion, the logistic regression analysis findings established that higher education levels significantly influenced adaptations. In contrast, demographic factors of gender and age and size of the farm were not major predictors of adaptations (Limo, 2013). It was envisaged that the results of this study would differ from the above study due to differences in regions and types of crops used. Age as a demographic factor had previously been found to be a more significant determinant of farming activity and manipulation of coping strategies within the Republic of Kenya. A very recent study by Simotwo et al. (2018) found that the small scale farming in Kenya is dominated by an average of 40 years middle-aged population. Concerning the marital status of small scale farmers, several studies had pointed out that single-headed households are potentially vulnerable to weather-related challenges in farming. This is mainly due to poor and limited decision-making on coping mechanisms to climate variability (Mikalitsa, 2010; Khisa et al., 2014; Oluoko-Odingo, 2011).

Another study conducted in Kiambu, Kenya by Kiarie (2016) examining the detrimental effects of climate fluctuation on small-scale farming adaptations, found that farmers who discovered a temperature rise were adapted faster than farmers who did not detect a significant increase in temperature. Similarly, farmers who noted a rise in rainfall were less adapted to climate variability than farmers who did not notice an increase in rainfall. These results were interpreted that the likelihood of learned farmers adjusting to the effect of climate variability was greater than the less fairly-educated small scale farmers; (i.e. $r=0.00$, and $p<0.01$). The primary adaptation strategies observed in this region were growing fast-maturing crop varieties, mixed crop farming, increased application of fertilizers and changes in planting dates. This situation could be different in Nyandarua County since the two regions have different climatic conditions, agricultural systems, education advancement, and technological empowerment. The study recognised that climate variability was evident, and a small number of scale farmers had adopted many adaptation strategies. However, these adaptations have not been well assessed, documented and classified according to the scheme set by IPCC 2015. The study did not outline the specific agricultural system considered, whether horticulture, subsistence, greenhouse farming or commercial. Since adaptation strategies differ from one agricultural system to another, there was a need to be specific, like what the current study has done by selecting certain food crops of maize and Irish potatoes for the study.

In Kenya, farmers near urban centres have relatively high adaptive capacity. Lack of adaptive capacity is expected in the remote and interior sections of the country (Mwangi et al., 2020). This could be attributed partly due to the accessibility of social amenities, good infrastructure and the contribution of other socio-economic features. The drier parts of Ndaragwa Sub County in Nyandarua County were expected to have low adaptive capacity because of their isolation and subpar living conditions.

## 2.9 An overview of adaptation to Climate variability in Nyandarua

In collaboration with the national government agencies like NEMA and KMD, the County government has come up with several measures to combat climate variability and promote sustainable adaptation strategies. Enforcement laws regarding encroachment of wetlands, riparian lands and forests have been put in place to reduce the incidences of environmental degradation. The silted reservoirs such as Lake Ol bolossat have been marked for de-silting to enhance water retention, reduce human-wildlife conflict, and increase water for agricultural, domestic and livestock use. Greater public awareness has been made of the need to plant more trees on public lands and farmlands and increasing effort to develop many other alternative and clean sources of energy such as use of energy-saving jikos, biogas, electricity, solar energy as well as embracing a carbon credit program. Farmers in Kipipiri and Ndaragwa dry zones must be encouraged to adopt greenhouse farming, practice irrigation farming and plant drought-tolerant crops for enhanced productivity. To support them, the County government has embarked on the assessment and erection of versatile dams for farming and livestock drinking.

In conclusion, adaptation is one of the best approaches for reducing the adversative climate variability's effects on crop farming and cultivation. However, it needs to be understood and assessed, mainly when it is interchangeably used with mitigation. There are choices for adaptation, and they differ depending on the area of the nation and the globe. Due to the variance in the local environment, specific suggestions might not apply to the entire region (Seppala et al., 2009).

Adaptation options depend on specific changes in a region and a range of other factors. Thus more research on climate variability and adaptations to agriculture needs to be done across the entire region because of the unique adaptation characteristics. In addition, while much research has been done on climate changes and variabilities, there are still significant gaps in the knowledge of the most appropriate adaptation strategies for agriculture in different regions worldwide. This is because the majority of adaptation strategies in agriculture that have taken place are planned, while others have been spontaneous due to the perceived risks and constraints (Adger, 2001). The literature review shows that numerous studies related to climate and weather changes, variability of climate and agricultural variatons may have been satisfactorily done across the globe. However, conflicting policies between levels of government create challenges for farming. Associated with this gap is that the level of farmers' choices to adapt and adjust to the effects and impacts of climate variability sometimes does not match the national and local government policies. In this case, farmers make adaptation decisions in a context of uncertainty brought about by climate variability. On the basis of this uncertainty, this study is designed to fill these gaps by assessing climate variability and its significant contribution to agricultural output in Kenya and evaluating how specific demographics and socio-economic factors have influenced the farmers' adaptation strategies and their effectiveness in maintaining and improving crop output.

## 2.10 Agronomic practices and other factors influencing crops output

Review of several literatures indicates that climate variability is the most significant aspect in determining the output of maize and Irish potatoes. In addition, agronomic factors and practices also play a major role in determining the yields of certain food crops (Ingram et al., 2008). These agronomic factors influencing crop output may include land tillage, fertilizer and manure application, seed varieties, pest and diseases control, weeds control, irrigation, harvesting and after-harvesting techniques. According to Ingram et al., (2011), the influence of climate variability conditions on crop farming cannot be addressed without mentioning the contribution of some agronomic factors. However, the impacts of certain climatic variables on crop output, yields and revenues can be determined in isolation by holding the agronomic variables constant in a regression model. In this study, the variation in maize and Irish potatoes' output could result from climate variability and some agronomic factors. To ensure that these factors were held constant in determining the effect of climate variability on maize crop and Irish potatoes output, the agronomic variables obtained during the administration of questionnaires were included in the regression analysis as control or moderating variables.

Based on the reviewed literature, it appears that considerable research on climate variability and agricultural output concentrated on assessing the various aspects of crop farming, e.g. amount of crop yields, and the influence of pests and diseases, among others, with little consideration to the socio economic features of small scale farmers (Mendelsohn et al., 2007). Many studies focusing on climate variability's effects on crop farming have been undertaken at a relatively large scale, e.g. global, regional, or country/nation (Thornton et al., 2009). The field of adaptation in a small local sector and specific region requires more comprehensive information for effective implementation. In addition, although small scale farmers have a fairly long history of adapting to the impacts of climate variability through a series of activities, climate variability brings new threats often beyond the existing experiences. The new adaptation strategies applied by both the commercial and small holder farmers are also exposed to the new risks of climate variability. There was a need, therefore, to assess and document these strategies in a more specific region like a County, as required by IPCC (2015) and Pachauri et al. (2015). This requires detailed and ongoing studies and research on the effects and contribution of climate variability on rain fed agricultural zones. The current research provided an opportunity to fill such knowledge gaps.

In terms of factors influencing the adaptation strategies, different arguments on factors and determinants such as gender, age, size and ownership of the farm were presented in their findings. Some of these factors significantly influence adaptations, whereas others reported that they are insignificant (Nhemachena & Hassan, 2008, Deressa et al., 2010). The researcher identified a knowledge gap, prompting them to compare Nyandarua County's findings with similar literature review findings.

Regarding the effect of age and gender on climate variability adaptation, it was likely that old-aged household respondents may be more experienced in farming but have less diversity of adaptation mechanisms. By bridging the gap of actual adaptations applied, the study made a critical contribution to adaptation research in Kenya. Finally, the study was particularly beneficial in knowledge acquisition and capacity enrichment.

One of the expected new contributions in the topic of climate variability, adaptations and crops yields/output from this research is the methodology of assessing and evaluating the impacts and effects of climate variability on selected crop yields while holding other factors that may influence crop yield constant. These factors may include agronomy practices, seed varieties, market forces, pests and diseases and soil fertility. This was done by ensuring that the Pearson Correlation and Multinomial regression procedures adhered to the assumptions of linearity and homoscedasticity. A new methodology of partial correlation coefficient procedure and stepwise regression analysis between climatic variables and crop variables were carried out so that the strength of each variable could be isolated. This was done by correlating two variables (Dependent and Independent) at a time while holding the other variables constant.

Regarding determinants of adaptation strategies, the results of this study made an essential contribution to the continuously evolving and limited observed and empirical evidence on the effect of gender and age within households on the adaptation tactics employed by the small scale farmers. This new knowledge will help to answer the following philosophical questions; does gender affect the types of adaptations employed? If yes, what are the underlying factors that bring out the differences between males and females? Between age and experience, which one influences the types of adaptations employed? What could be the underlying factors behind the age and experience of a farmer in response to climate variability?

## 2.11 Constraints of adapting to climate variability's effects in crop farming

An attempt to address adaptation strategies in the context of many small scale farmers in SSA raises specific challenges and limitations (Jin et al., 2015). These challenges cannot be addressed adequately by the usual agronomic studies in agriculture (Ludgate, 2016). This is owing to the influence of critical environmental and socio-economic considerations, such as the influence of issues of climatic factors variability on crop farming (Adger et al., 2003). In this context, Claessens et al. (2012) classified the adaptation constraints into two levels; Low adaptation challenges and high adaptation challenges. Common adaptation challenges involve high poverty rates among small scale farmers.

In contrast, high adaptation challenges have to do with poor policy-making on coping with climate variability's effects. According to Simotwo et al. (2018), the high-level challenges emanating from the downstream and upstream include the increased costs of farm inputs such as hybrid seeds and fertilizers, poor road networks, and limited access to micro-credit facilities, among many others. Mutanga et al. (2017) noted that limited land sizes and poor land tenure systems are some common challenges in many ethnic communities in Kenya. This contributes to the slow adoption of effective adaptation measures and sustainable farming practices.

Furthermore, the old way of land inheritance among many communities in Kenya has led to an acute subdivision of land, which has become uneconomical to cultivate (Wiesmann et al., 2014). Musingi and Ayiemba (2012) highlighted that with enhanced access to higher education, farmers are endowed with technical, social and financial capital. These skills and resources help solve the adaptation challenges to climate variability.

Research on environmental challenges affecting food security in various countries reveals numerous constraints for small scale farmers (Techoro, 2013). The negative impacts of climate variability may be devastating, making it challenging to develop appropriate action responses. Poverty and inadequate resources hinder farmers from accessing necessary adaptation technologies (Vysochyna et al., 2020). A study by Wambua, Telesia and Omoke (2014) found some empirical and practical evidence that the lack of adequate arable lands and other farming resources and capital are some of the underlying challenges for practical adaptations and, consequently, food insecurity in Kenya. These factors alleged by the small scale farmers contribute to their adaptive capacities being ineffective and vastly overwhelming (Ochieng et al., 2016). Lack of water for irrigation has also been cited as a significant problem hindering effective adaptations among many small scale farmers in Kenya. According to Hosea et al. (2016), among the many challenges facing water-fed agriculture is the inadequate source of finance needed for their implementation. Kithiia (2019) proposed that the collaboration between stakeholders allows the sharing of costs and available resources from different players to combat the challenges of climate variability. Climate variability significantly affects small, fragmented farms with limited access to agricultural extension services, income and credit, suggesting the need for sustainable water management solutions. (Mutisya, D. & Wamicha W.N. 2000)

Recognizing these climate variability and adaptation challenges, the Climate Change Response Strategy (NCCRS) unit was established in Kenya. Their mandates are to respond and react to the constraints and opportunities presented by climate variability (Rok, 2010). The main focus of NCCRS is to foster the national strategic plans and actions toward effective adapting to climate variability. This is done by ensuring that all the stakeholders in the country are engaged in combating the impacts and effects of climate variability, especially when considering the vulnerability of the natural and ecological resources of the society as a whole (Ochieng et al., 2016).

## 2.12 Theoretical Framework

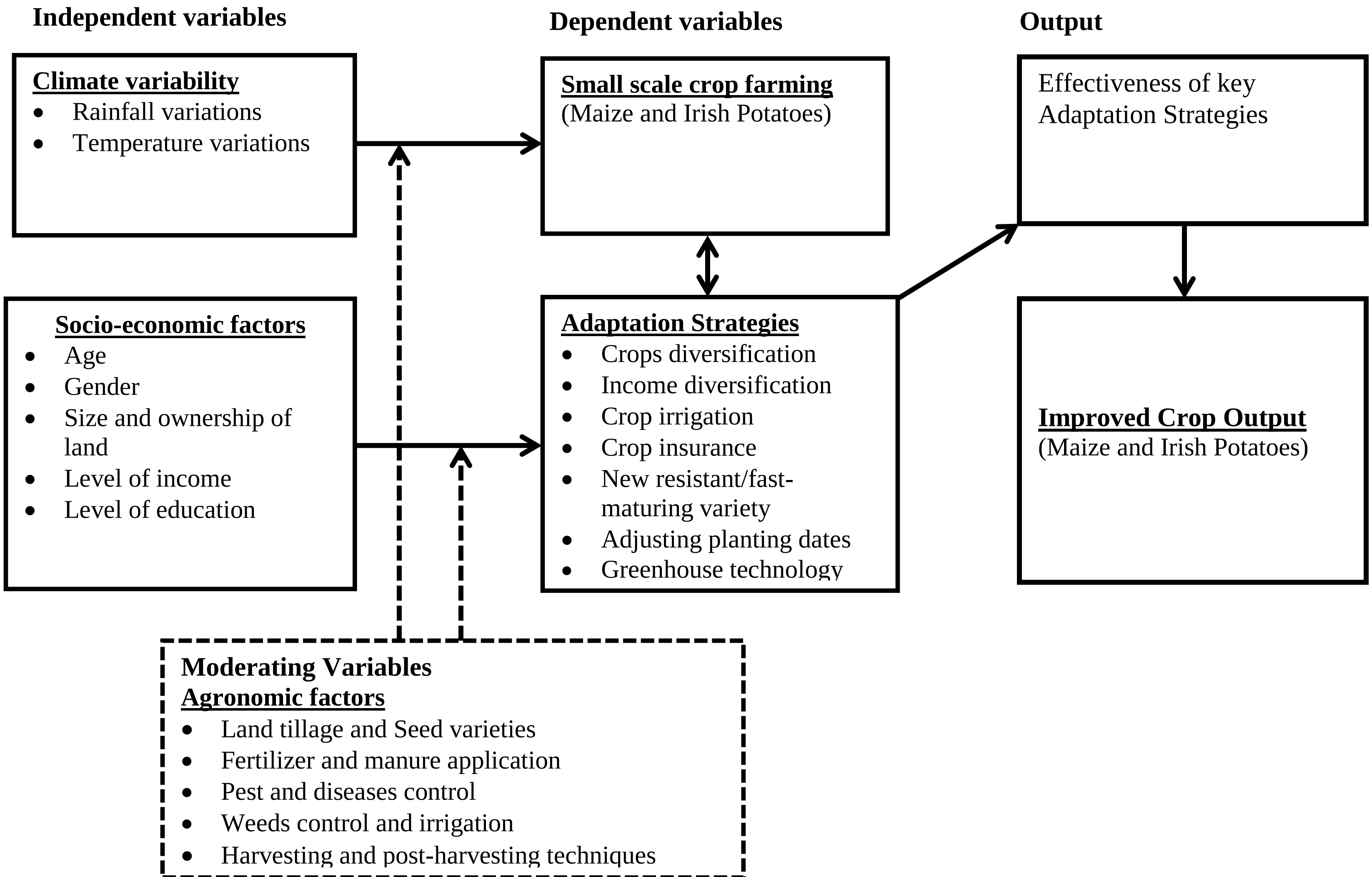
The theory was established by Mendelsohn et al. in a study conducted in 2007 that examined analysed the effects of climate change on agriculture in USA. To accomplish the objectives of these studies, Mendelsohn et al. (2007) developed this theory to countercheck the shortcomings that other traditional models had of overestimating the harmful effects to agricultural output because of climate variability. The bias in the previous studies were caused by the failure to include the adaptation measures and strategies for changing climatic situations, but as stated by Mendelsohn et al. (2007) and World Bank, (2009), the theory effectively incorporates farmers' efficient adaptations. The Ricardian model does not rely on complex crop yield models but instead is a simple cross-sectional technique that assesses the empirical relationship between crop output and climate variables. Based on this theory, crop outputs are regressed on climatic and other socio-economic variables. This theory relies on the notion that climatic factors and proper adaptation measures determine agricultural crop output. In contrast, certain socio-economic and agronomic factors are essential in control variables. A critical benefit of this method is that it controls the adaptations that farmers make to climate variability. In this regard, the technique assumes that farmers in future will be as flexible to climate variability as the current farmers are (Deschenes, 2007). The model has gained popularity in recent times. It was recently used to assess whether climate variability impacted agricultural revenues in Central Asia (Alisher, 2013). Besides the above study, the Ricardian theoretical model has been applied widely in African countries; (Seo & Mendelsohn, 2007). Unfortunately, a broad study of Kenya using the model is still missing. The current study filled that gap by applying the Ricardian method to a significant section of Kenya. Despite some strengths, the Ricardian method as a technique has got some limitations. The approach fails to fully consider the impact of critical explanatory variables such as soils, agronomic practices and market forces that could also account for the variation in crop output. Another weakness lies in the potential bias caused by omitted variables that are not directly related to climate variables. The omitted variables could result from incomplete and inaccurate data on crop output and climate variables. These limitations weaken the Ricardian approach though it was still the most appropriate for this study (Mendelsohn 2010). The Ricardian approach was preferred for this study because it incorporated the alternative activities that each small scale farmer had accepted against the existing climate variability situation (Wrigley-Asante et al., 2017). One of the most significant advantages of this theory in the current study is that it was not expensive since primary and secondary data on climate variability, crop output and socio-economic variables on cross-sectional sites were relatively easy and cost-effective to collect (Deressa & Hassan, 2009). Due to these strengths, the Ricardian theoretical model was used to develop a conceptualized framework for the current study.

## 2.13 Conceptual Framework;

The conceptual framework (figure 2.1) for this study builds its interactions between the independent climatic variables of climate such as temperature and rainfall and socio economic factors with dependent variables of crop output and adaptation strategies. From the conceptual framework, the dependent variables of maize and Irish potato yield variations have been connected to the independent variables of rainfall and temperature variations. Changes in these climatic variables may impact crop farming negatively or positively. The study addressed the negative impact of climate change variability on crop output. The conceptual framework also recognizes the input of agronomical factors in the output and productivity of crops. These factors were treated as moderating factors to the interaction between independent variables of socio economic factors and the dependent variables of adaptation strategies and crop output. In this study, these factors were not analysed in testing the hypothesis. The framework further describes the interactions between adaptation strategies, their determinants and crop output. The dependent variables of adaptation strategies by small scale farmers been connected to the independent factors of farmers' demographic and socio-economic factors of age and gender, size and ownership of land, farmers' level of education and income. The socioeconomic characteristics of the small-scale farmers affect the adaptation strategies adopted, which determines the prospects of agricultural productivity. On this basis, the effectiveness of farmers' adaptation strategies have been evaluated and assessed using statistical tools to make informed decisions. The conceptual framework referred to as figure 2.1 pays attention to the inter linkages of climate variables, socioeconomic factors, small scale crop farming adaptation strategies and the expected results of improved crop output due to the effectiveness of key adaptation strategies.

Recommended policies and action plans have then been formulated based on the findings to guide policymakers and small holder farmers in responding to the future impacts and effects of climatic variability on crop farming agriculture. These action plans of adopting effective adaptation strategies ensure sustainable crop output despite the continuous variations in climate. This conceptual framework summarizes the whole study in terms of problem statement, objectives setting and hypothesis formulation, the three chapters of data analysis and findings and recommendations for action plans.

**Figure 2.1: Conceptual Framework;**




Complete arrows: Describe the inter linkages between variables under investigation.
Dashed arrows: Describe the association and inter linkages of variables not under investigation.

Source: Researcher 2023

## 2.14 Summary of Literature Gaps

Despite extensive research on the topics of climate change and variability, there are significant gaps in knowledge on appropriate adaptation strategies for agriculture in different regions. This is so because adaptation options depend on specific regional changes and other socio-economic factors. More research is needed on climate variability and adaptations to agriculture due to unique adaptation characteristics. The gap in agricultural adaptation strategies, despite being planned or spontaneous, is exacerbated by conflicting government policies, posing significant challenges for farming. This is according to Adger, (2001). Rakib & Matz (2014) highlight that farmers' adaptation choices often conflict with national and local government policies. The gap emanating from this relationship is that farmers develop their adaptations in a context of uncertainty broughtt about by climate variability. Singh et al. (2020) highlight the lack of assessment and documentation of farmers' adaptation strategies, which could be influenced by environmental and socio-economic factors, affecting vulnerability or resilience to climate variability. Mburu's (2013) study in Yatta District found the small scale farmers adopting climate adaptation measures to be like drought-resistant crops and rainwater harvesting. However, it failed to examine regions like Nyandarua County, which rely heavily on rain fed agriculture. Suvedi and Kaplowitz, (2016) indicated that income diversification is linked to asset households' endowment, rural proximity, population factors, migration trends, and food security sensitivity. Nyandarua smallholder farmers' adaptation strategies to climate variability had not been thoroughly evaluated. Mudzonga (2012) and Ozor et al. (2012) found that education significantly impacted farmers' adaptations to weather and climate variability in Zimbabwe and Nigeria, respectively. The gap between these studies was based on the methodologies used. Mudzonga (2012) used the Multivariate Logistic Model, while Ozor et al. (2012) used the Probit regression model. The current study used a Correlation and Multinomial regression model for more accurate results. Seppala et al. (2009) highlighted the need for comprehensive research on climate variability topic and adaptations to agriculture, highlighting the unique characteristics of these adaptations and the significant knowledge gaps in global knowledge. Pachauri et al. (2015) highlighted that small scale and large scale farmers adapt to climate variability through various activities, but often face new threats beyond their existing experiences. Nhemachena and Hassan's (2008) research on factors influencing adaptation strategies revealed varying degrees of influence, with some being significant and others insignificant, highlighting a knowledge gap in the literature review. Deressa et al. (2010) found that older household respondents may have more farming experience. The gap is they may have less diversity in adaptation mechanisms, contributing to Kenyan adaptation research. The Ricardian theoretical model, popular in Central Asia and Africa, had been used to assess climate variability's impact on agricultural revenues, but a comprehensive study of Kenya using the model was missing. In conclusion, current research aimed to fill knowledge gaps by assessing and documenting adaptation strategies in specific regions, specifically in rain-fed agricultural zones, as required by IPCC (2015).

## 2.15 Deduction from Literature Review

Based on the literature review, conceptual framework and research methodology, the following conclusions were made;-

1. This study highlights the need of continuously monitoring what happens in the mitigations and adaptations arena and how these adaptations influence the well-being of small scale farmers. This is because the interaction between climate variability, its impact on crop farming and the application of adaptation strategies are very dynamic.

2. The study provides more insights and adds to existing literature and knowledge on the evolving but still limited theoretical and empirical evidence on the relationship between climate variability, its impact on crop farming and the application of adaptation strategies guided by certain vital determinants.
3. The study findings have crucial implications to the policy makers for policies that can support small holder farmers to cope up with the impacts of climate variability.
4. The study's results regarding the three main adaptation strategies have further supported the advantages of the Ricardian Empirical Model that allowed the inclusion of adaptation responses.
5. The empirical output model adds a new aspect to the existing knowledge of the Ricardian model, which provides optimistic and more accurate results regarding the unprecedented climate variability's impacts on crop farming and adaptations than generally the doubtful results found in purely agronomic studies.
6. The study results give reliable evidence about the importance, usefulness and application of the conceptual framework in policy formulation for effective climate variability adaptation strategies.
7. Applying both correlational and regression techniques in the data analysis methodology makes the current study's results more accurate and meaningful. This adds knowledge to the existing literature on better application of multiple inferential statistics within the same related investigations.
8. Any theoretical framework in the field of climate variability and crop farming contains three fundamental issues that should be directed to the livelihoods of the communities;
    a) Exposure

b) Sensitivity

c) Vulnerability

9. Sustainable and effective adaptation strategies in crop farming to climate variability should combine the three critical aspects.

a) Community socio-economic predispositions on adaptations to climate variability.

b) Government integration into policies regarding adaptation to climate variability.

c) Adaptation strategies based on spatial ecosystem environments.

# CHAPTER THREE

# STUDY AREA

## 3.1 Introduction;

This chapter hosts a comprehensive description and discussion of the study area presented in literature and tabular forms supported by maps, charts and photographs. It starts by building on the background of the study area information in terms of climate systems and agro-ecological zones in central Kenya. Nyandarua County has also been positioned using coordinates, size, population and other demographic features per constituency based on the 2009 census. Land use, environmental degradation, conservation, and agricultural productivity in the County have also been well documented.

## 3.2 Location

The study area is Nyandarua County, situated in Kenya's central region with a total surface area of 3,245.2km$^2$, lying between latitudes 0°50 'to the South and 0°8 'to the North and between longitude 36°42' West and 35° 13 'East. The Counties bordering Nyandarua include; Nyeri in East, Laikipia in North, Murang'a in South East, Nakuru in West and Kiambu in South (Muraya et al. 2016). The effect of volcanic eruptions and faulting resulted in major landforms and physical features in the County. The primary physical features include the Aberdare ranges to the East, to the West is the Great Rift Valley and some plateaus. The highest altitude peak of the Aberdare mountain ranges is 3,999m above sea level. The County boasts of eight permanent rivers: Turasha, Kiriti, Ewaso Narok, Mkungi, Kiburu, Malewa, Pesi and Chania. Some of these rivers drain their water in Lake Ol'bollosat, the only extensive water reservoir in the region. Over time, the weathering process has created shallow valleys and gorges on the steep slopes of the escarpments, resulting in changes in river channels and a series of faults resulting in shallow waterfalls. Most of the rocks in the area are of volcanic type. The soil in the region varies in fertility ranging from moderate to high fertile (Wasyombii et al., 2016). The County's ecological condition consists of some areas in the zone of savannah highland characterized by expansive grass cover and scattered trees. Tree cover is dominant in the highland zones. However, human encroachment has led to the overwhelming clearing of natural vegetation causing environmental perils such as land dilapidation and erosion, thereby reducing the size of arable land in the County. This encroachment has led to negative consequences such as warming of the globe, changes in climate, reduced rainfall, increased soil erosion and reduced food production.

## 3.3 Administrative and Political units

Nyandarua County comprises five sub-counties that also form the County's constituencies. They are Ol'joroOrok, Ndaragwa, Kipipiri, Kinangop and Ol'kalou. The largest sub-County is Kinangop, with six divisions and sixteen locations. Kinangop comprises the most electoral wards, adding up to eight, with Ol'kalou second comprising five electoral wards. The other three constituencies each comprise four electoral wards.

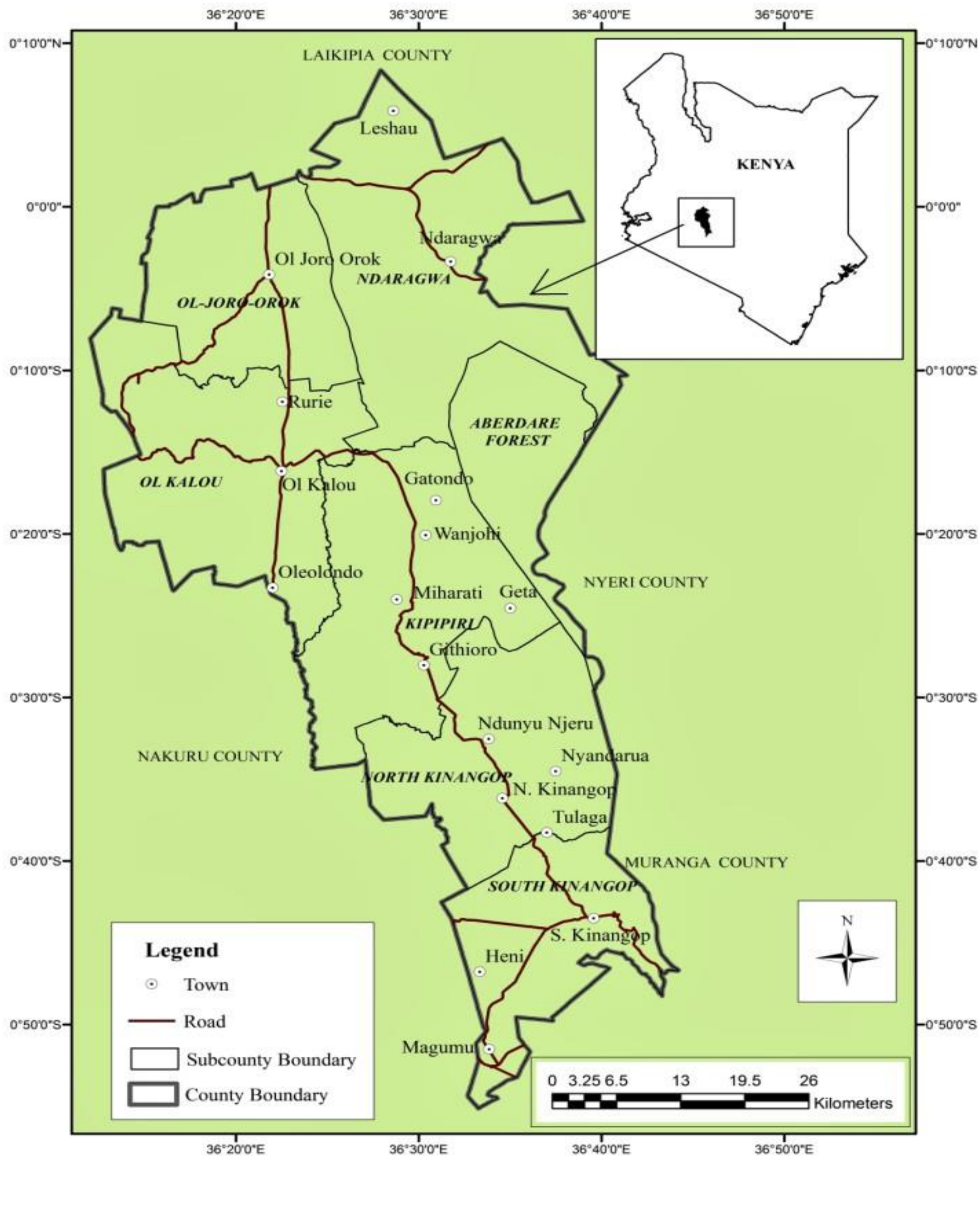
Ol'kalou has eight divisions and twenty-one locations. Kipipiri has three divisions and twelve locations. Ndaragwa has four divisions and thirteen locations. Ndaragwa constituency covers an area of 903.7Km$^2$ all-encompassing the Aberdare forest becoming the largest after Kinangop, which covers 822Km$^2$. However, when the Aberdare forest reserve is excluded, Ndaragwa remains 653.6 Km$^2$ of habitable land, becoming the second largest. Ol'joroOrok Constituency is the smallest sub-County covering a total surface area of 389.1 Km$^2$ with four divisions and 8 locations.

**Table 3.1: Political and Administrative units of the County**

| Sub-County/ Constituency | Area ($km^2$) | No. of Divisions | No. of electoral wards | No. of Locations |
|---|---|---|---|---|
| **Kinangop** | 822.0 | 6 | 8 | 16 |
| **Ndaragwa** | 653.6 | 4 | 4 | 13 |
| **Ol'kalou** | 586.7 | 8 | 5 | 21 |
| **Kipipiri** | 543.7 | 3 | 4 | 12 |
| **Ol'jororok** | 389.1 | 4 | 4 | 8 |

Source: County Government's office, Nyandarua County, 2012

**Figure 3.1; Map of Nyandarua County (The Study Area)**



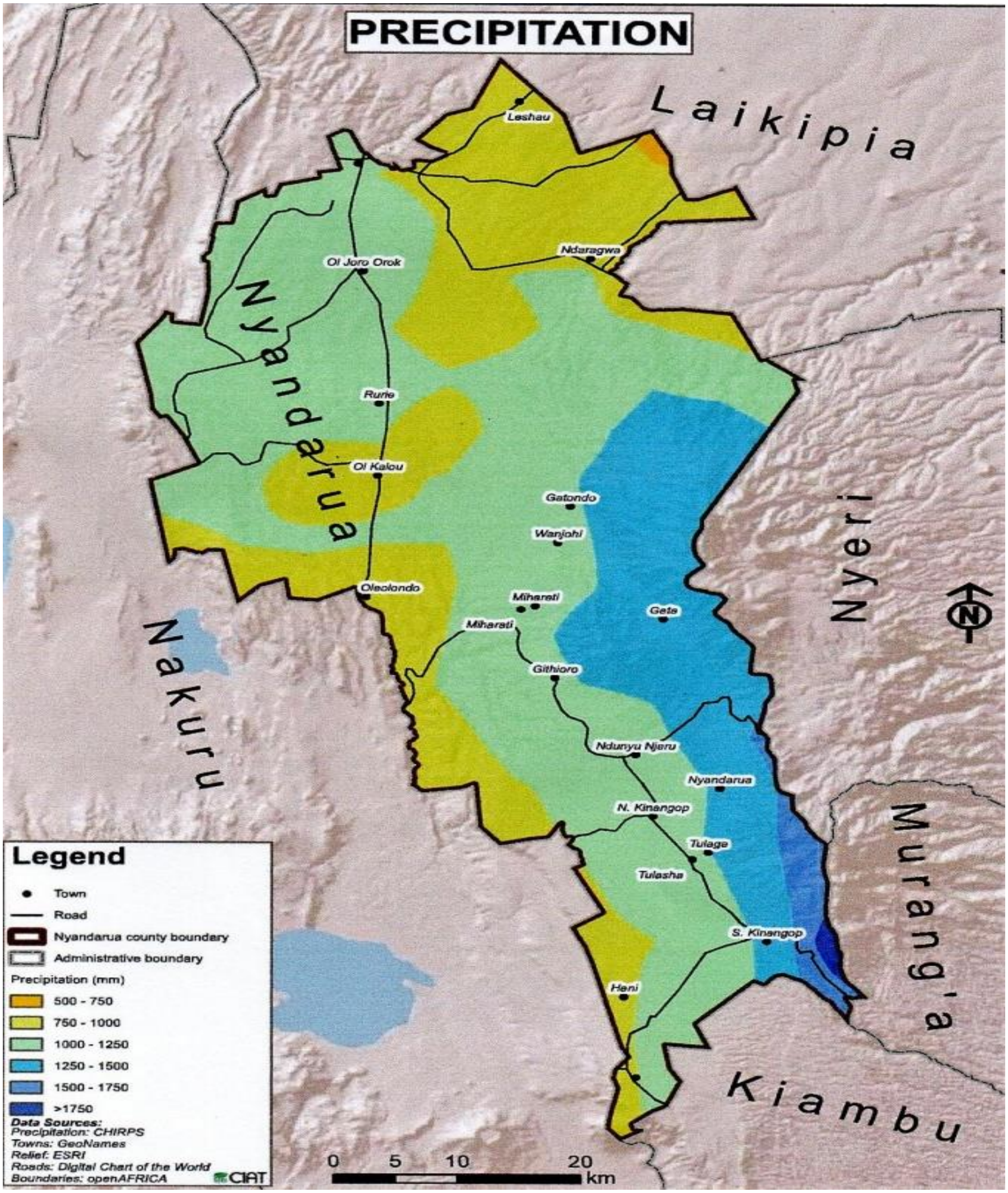

Source: Researcher 2019

## 3.5 Climatic Conditions in Nyandarua County

The equatorial climatic zone of Nyandarua County experiences low temperatures at night to moderate temperatures during the day that favour growth of some crops like Irish potatoes. The coldest temperatures in the past have been recorded in July, with the average mean temperature dropping below $12^0$ degrees Celsius. On the other hand, the highest temperatures were recorded in December, with the mean temperature reaching 25°C. During flawless nights, cold air upsurges in the Aberdare Mountains' slopes and moves down the West of plateau basins, where temperatures drop to $-1.3^0$C for a brief period before the rise of the sun. Short rains with a maximum of 700mm in the month of September to December and long rains with an extreme of 1600mm from March to May are the two bimodal rainfall seasons in the County (Omwoyo & Akivaga, 2015). However, rainfall intensity varies by location, with places near Aberdare slopes receiving ample rainfall and plateaus receiving brief and erratic rain.

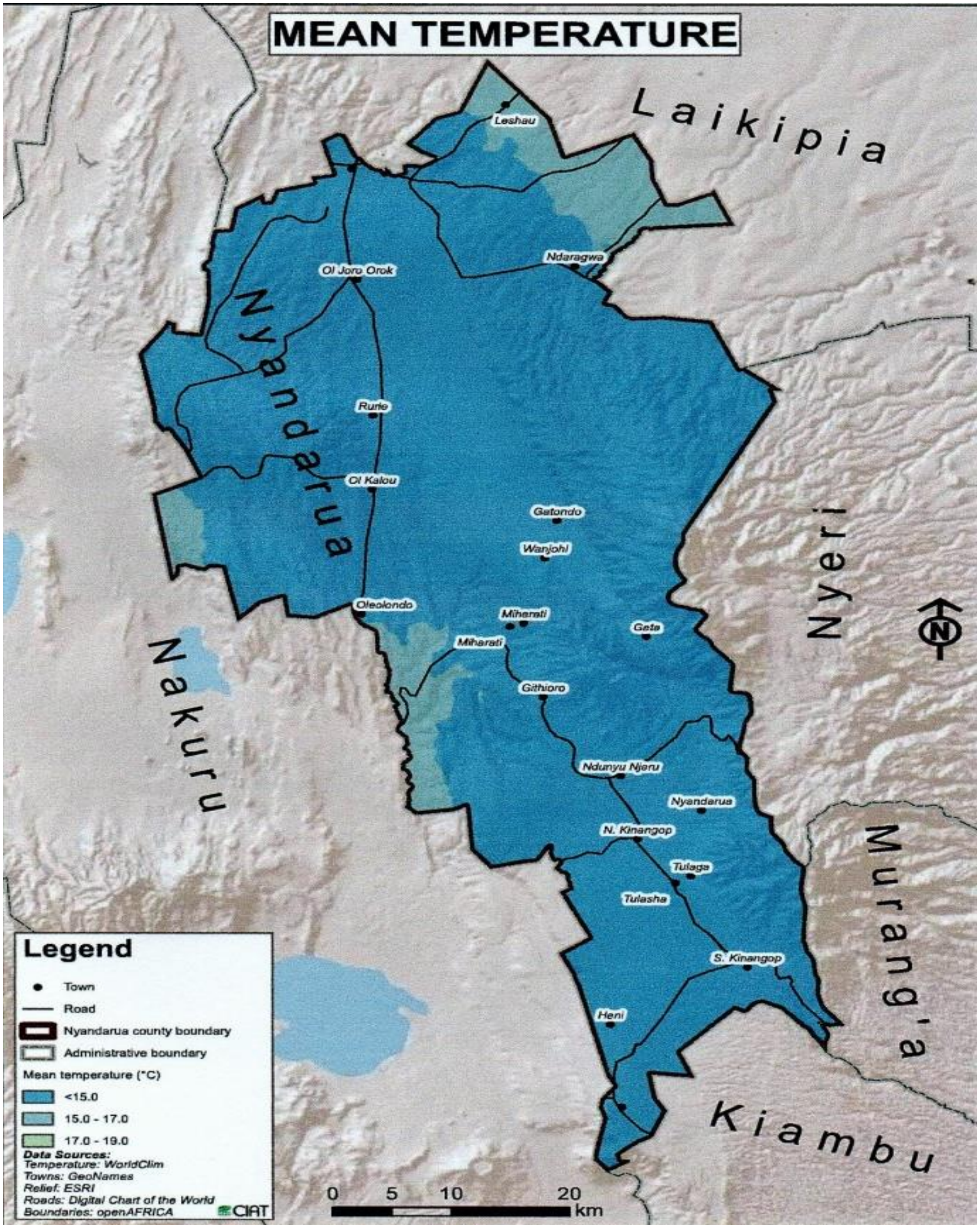
The common types of crops grown and cultivated in the County include maize, wheat, vegetables, and Irish potato crop. Because some of these crops are sold, they provide a substantial livelihoods and sources of incomes for most households in Nyandarua (Kaguongo et al., 2007). Of the 184,900.0 ha of arable land in Nyandarua, only 96,062 ha are farmed. Current meteorological circumstances have revealed that some County regions are experiencing dry spells and shallow temperatures, resulting in crop let-down and lower crop production yields (Jaetzold et al., 2007).

**Figure 3.2: The region of Nyandarua's precipitation**




Source: The 2017 Kenya’s county profile of climate risks

**Figure 3.3: Mean Temperature in Nyandarua County**




Source: The 2017 Kenya's county profile of climate risks

### 3.5.1 The climate variability's impacts on crop agriculture in Nyandarua

Since the global patterns have changed and conclusions from climatic statistics data from KMD have been made, it is evident that Nyandarua County has seen a change in climatic conditions over a number of years extending up to a decade. In the past, the County used to experience rainfall throughout the year, unlike nowadays, where the County experiences two distinct rainfall seasons. The first is shorter and spans from September to December, whereas the long rains are from March to May. This change in meteorological conditions has interfered with farming designs in Nyandarua County because some areas in the north especially Ndaragwa Sub-County nowadays experiences frequent periods of food shortage due to crop failure. The shallow temperatures at night have led to cases of crop failure due to cold bites.

## 3.6 Population

The last National Kenyan Population Census that was carried out in 2009 the population of the County at 596,268. This population density comprised 304,113 females and 292,155 males (Devolution hub, 2018). The County's population growth rate had been estimated to grow at 2.4% annually, projecting the population to grow to 656,348 by 2013 and 688,618 and 722,498 people in 2015 and 2017, respectively (Census, 2009). The County's land cover and use have been greatly impacted by the high rate of population growth. Due to market factors and the high rate of population expansion, small scale farmers have subdivided land in Nyandarua County and settled. Only very few large farms exist in the County. On average, a household occupies 3.5 hectares of land. With the current population growth trend and urban centres' development, the land sizes owned and settled are likely to shrink as land fragmentation and land sale continues (KDHS, 2013).

## 3.7 Land use in Nyandarua County

Land use in Nyandarua may be categorized into forestry, agricultural, national park, township, roads and water bodies. Agricultural land use contributes the largest share. Most of the small farms in Nyandarua are situated in areas initially occupied by white settlers during the colonial era. Small scale farmers primarily practice mixed cropping and livestock keeping (Kibuuka & Karuggah, 2005).

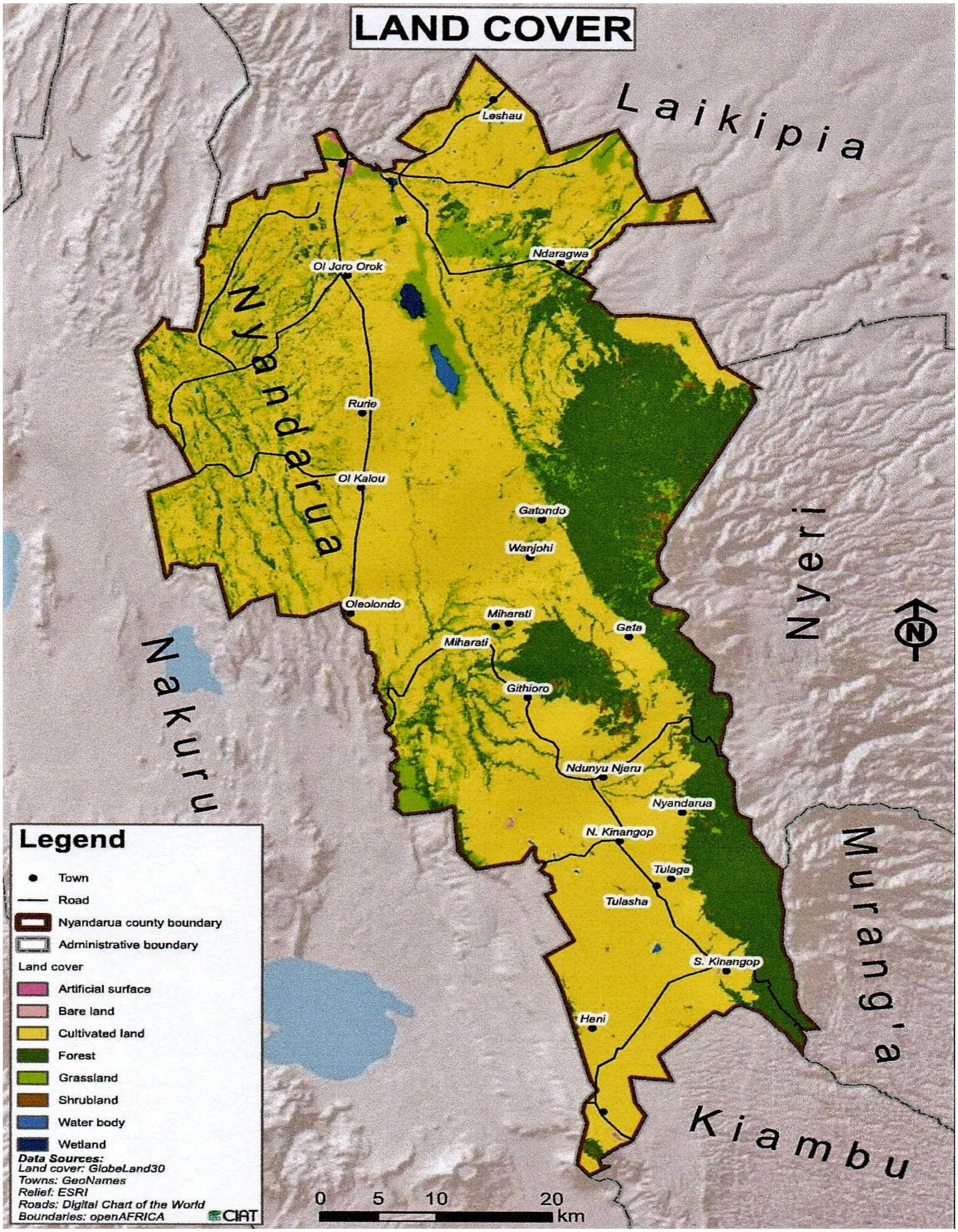
Small-scale farmers have substantially subdivided and populated the land in Nyandarua County as a result of the county's rapid population increase and market factors. Only very few large farms exist in the County. On average, a household occupies 3.5 ha of land. With the current population growth trend and urban centres' development, the cultivated and owned land sizes are likely to shrink as land fragmentation and sale continue. Land use in Nyandarua may be categorized into forestry, agricultural, national park, township, roads and water bodies.

**Table 3.2 Land use and area covered in Nyandarua County**

| **Land use** | **Sq. KM Area** | **%** |
|---|---|---|
| Built-up Areas | 38.2 | 1.2 |
| Farm Land | 2,147 | 65.7 |
| Protected & Hilly Areas | 1,033.6 | 31.6 |
| Wetland | 28.10 | 0.9 |
| Water Body | 23.20 | 0.7 |
| **Total** | **3,270.12** | **100** |

Source: The 2018-2022 Integrated County Development of Nyandarua.

**Figure 3.4: The Land use of Nyandarua County**




Source: The 2017 Kenya's county profile of climate risks

## 3.8 Declining crop output in Nyandarua County

The trend of essential crop productivity in Nyandarua County has been stable or declining over the years. This has been dramatically occasioned by climate variability where rainfall patterns have changed, and temperature levels have increased beyond optimum or too low to cause frostbite (Mburu B.K., 2013, Mwaura J.M., 2015 Limo WK, 2013). The heavy reliance on rainfall has dramatically reduced crop production, such as maize and Irish potatoes. The reduced agricultural productivity has further been worsened by the high and increased cost of inputs and capital, especially fertilizers, certified and authorized seeds and seedlings and spraying chemicals. In addition, several agricultural cooperative societies that used to assist farmers in improving their crop yields have collapsed. This suggests that affordable lending options are no longer available to a large number of farmers. Cheap inputs and proper education on how to improve their production are also lacking.

The major crops grown and cultivated in the County include maize, wheat, vegetables, and Irish potatoes. Because some of these crops are sold, they provide important sources of incomes and substantial livelihood sources for the popular number of the households. Of the 184,900.0 ha of arable land in Nyandarua, only 96,062 ha are farmed. More than half of the fertile area in Nyandarua County is used for crop production due to the county's rather consistent rainfall. Recent meteorological scenarios have revealed that some County regions are experiencing dry spells and extremely low temperatures, resulting in crop failure and lower crop yields. Nyandarua County, on the other hand, has a great potential for agricultural output because of effective adaptation mechanisms.

**Table 3.3: Production of Main Crops and Aggregate values in 2012**

| Crop | Production (Tonnes) | (No. Of Hectares) | Aggregate Value (Kshs-Millions) |
|---|---|---|---|
| Beans | 3065 | 6,812 | 183 |
| Cabbages | 164,370 | 10,958 | 821 |
| *Irish Potatoes | 461,657 | 36,446 | 5,935 |
| *Maize | 51,300 | 19,000 | 1,300 |
| Carrots | 23,170 | 2,317 | 231 |
| Kales & Spinach | 1,800 | 440 | 18 |
| Pyrethrum | 80 | 200 | 11.0 |
| Wheat | 16,605 | 4,100 | 442 |
| Total | 722,337 | 80,331 | 8,943 |

The 2018-2022 Integrated County Development of Nyandarua.

**Table 3.4: Production of Main Crops and Aggregate values in 2016**

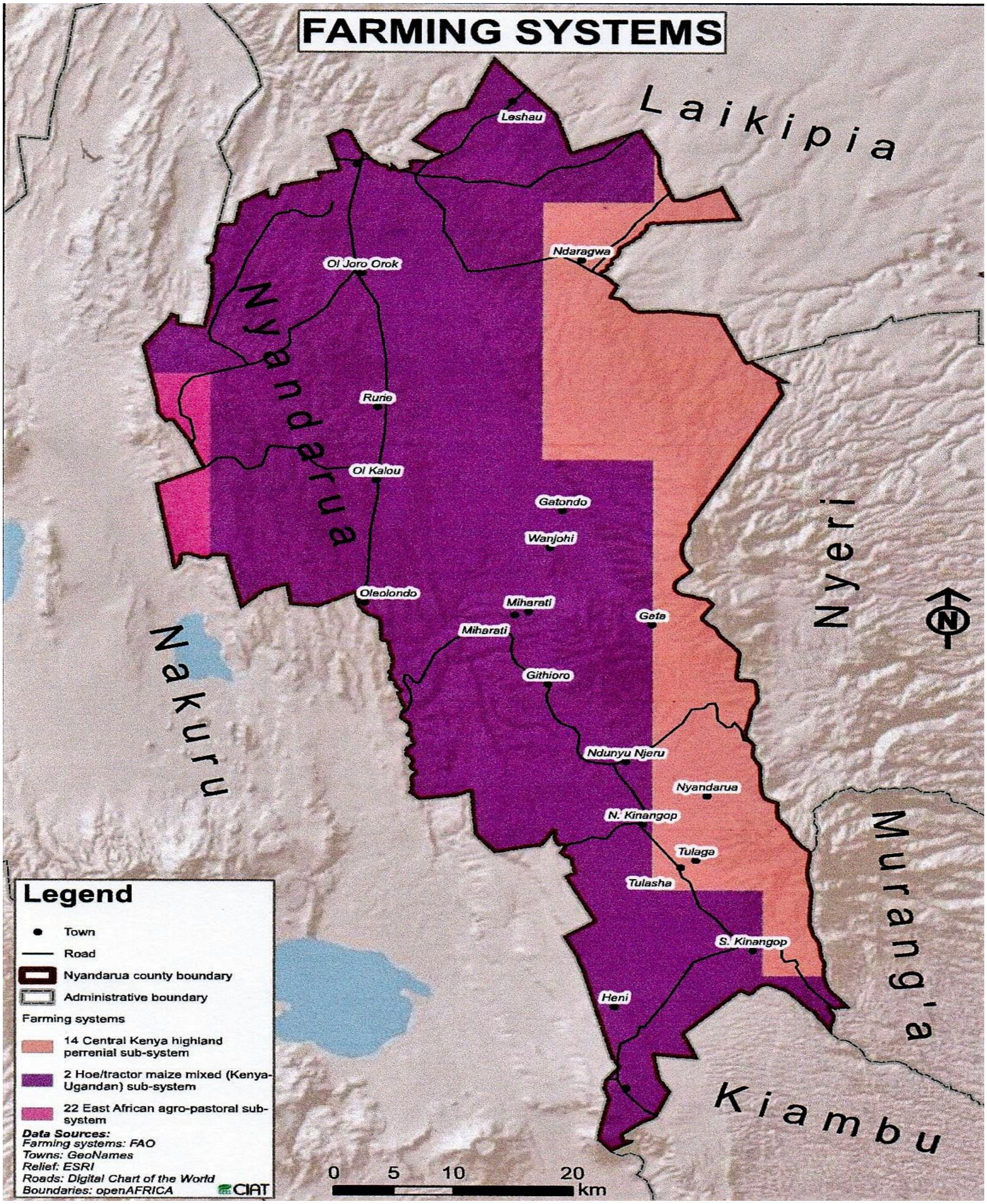
| Crop | Production (Tonnes) | (No. Of Hectares) | Aggregate Value (Kshs-Millions) |
|---|---|---|---|
| Beans | 988 | 4,152 | 69.2 |
| Cabbages | 280, 600 | 9, 200 | 1,400 |
| *Irish Potatoes | 451,290 | 33,035 | 8.12 |
| *Maize | 27,594 | 16,300 | 978 |
| Carrots | NIL | 1,150 | 345 |
| Kales & Spinach | 26,000 | 1,300 | 520 |
| Pyrethrum | NIL | 160 | 4.5 |
| Wheat | 9,729 | 3,520 | 324.3 |
| Total | 541, 601 | 60,917 | 4,169.12 |

The 2018-2022 Integrated County Development of Nyandarua.

*Crops considered in this study

Tables 3.3 and 3.4 above compared the crops yield in tonnes, acreage in hectares and total value in million Ksh for two years; 2012 and 2016. The two years chosen represented a five-year gap in the statistics for crop production. Analysis of the figures provided allowed for projections on possible performance five years ahead. From the statistics given by the County government, it is evident that the output of major crops like maize and Irish potatoes had been declining. Likewise, the size of cultivated land had also been reducing between the two years, from 80,331 ha in 2012 to 60,917 ha in 2016. These two occurrences have reduced the total earnings of the County from 8,943 million Ksh in 2012 to 4,961 million Ksh in 2016.

**Figure 3.5 Farming systems in Nyandarua County**




Source: The 2017 Kenya's county profile of climate risks

## 3.9 Average size of farms and agricultural storage facilities in Nyandarua

Land in Nyandarua County is recently experiencing subdivision into smaller pieces due to increased population and market forces. This land fragmentation is causing low productivity due to poor land use, loss of soil fertility and overuse. Most of the small farms in Nyandarua are found in areas initially occupied by white settlers during the colonial era. Farmers in the small farms primarily practice mixed cropping, livestock and agroforestry. The few large farms in the County are evenly spread, most of which is used for dairy farming and horticulture. The small-scale and holder farmers in the region have traditional silos with a capacity of 20-30 bags of maize or Irish potatoes. However, Irish potatoes and other vegetables may not be stored for long because they are highly perishable. Therefore, there is a need for adequate cold rooms and storage facilities for perishable agricultural produce as the only incomplete potato midland store at Kinangop for Irish potatoes has a maximum capability of 65,000.0 bags only. The lack of these facilities makes the farmers sell their produce directly from farms in many cases at a loss in fear of spoilage and hence wastage. Located in Leleshwa (Kipipiri) and Ol’kalou are only two National Boards for Cereals and Produce (NCPB) provisions with room capabilities of 50,000.0 bags and 100,000.0 bags, respectively.

## 3.10 Incidence of Landlessness in Nyandarua County

The colonial regime brought about the incidences of landlessness in the County, where farmworkers who used to toil for the white colonists continued staying in the previous labour campsites as squatters. Such areas include; Boiman, Gathanje, Githioro, Heni, Kaheho, Kanyagia, Magumu, Mukeu, Murungaru, Ndaragwa, Ndunyu Njeru, Njabini, Ol'kalou, Passenga, and Rurii. 2007 saw internally displaced persons flock in the County, exacerbating the number of people without a land. However, the government has dealt with this situation well since 2009, when most families have been settled outside and inside the County on acquired pieces of land. Nyandarua County IDPs have been established in Kaimbaga at olkalou, Kianjogu, Mawingo in kipipiri, Mbuyu, Ol'joroOrok, Salient, and Uruku settlements farms.

## 3.11 Degradation of Environment in Nyandarua

The incidence of human encroachment to Aberdare forest and Lake Ol'bollosat has caused a loss of vegetation cover due to human settlement, poor agricultural undertakings, and increased quarries. This encroachment has increased the vulnerability of land to topsoil erosion, reduced forest cover due to illegal felling down of trees for wood, timber and charcoal production, and threats of fire outbreaks. The long rains in 2018 saw flooding of high magnitude that had never been witnessed there before. This is attributed to human activities such as farming and construction, blocking natural waterways, and lacking proper waste and drainage systems. Due to environmental degradation, Nyandarua County has been affected by silting significant rivers and dams, reducing water levels. The evidence is that 151 dams out of 222 have been marked for de-silting. Because of this excessive soil erosion, loss of soil fertility, and unfavourable climatic conditions, Nyandarua County has experienced reduced agricultural production. Farmers have been forced to use costly and unaffordable fertilizers, but the production is still low. Cases of human-wildlife conflict have also been noted due to encroachment of Aberdare forest and Lake Ol'bollosat. Moreover, the increased surface runoff due to erratic rainfall has reduced water flows in major rivers, reducing water availability for agricultural, home, and livestock use.

## 3.12 Energy Access

The main energy source for cooking is firewood, although electricity is available in 10.5 per cent of the County, primarily in the urban centres of Njambini, Ol'kalou, Mairo-inya in Ndaragwa and Engineer. There is also a growing population with access to electricity scattered in trading centres across the County. Only 0.2 per cent of homes use electricity for cooking, while 77.8% of households utilize firewood biomass as their principal fuel source for cooking. Charcoal is used by 19.3 per cent of houses, paraffin by 1.4 per cent and biomass residue by 0.3 per cent. Firewood is used by 0.3 per cent of households; paraffin is used by 82.7 per cent, electricity is used by 10.5 per cent, and solar is used by 6.0 per cent.

## CHAPTER FOUR

## RESEARCH METHODOLOGY

### 4.1 Design;

The descriptive study and survey design was utilized to analyze small scale farmers' adaptation strategies, utilizing a checklist and questionnaire responses. This design allowed researchers to draw conclusions and inferences from a sample population without control over dependent and independent variables.

### 4.2 The analytical unit of the study population

All of the small-scale farmers in Nyandarua County were included in the study's target population and sample frame. The Kenya Bureau of Statistics had published an estimated number of 6,000 small scale farmers' households in its 2019 survey. The unit of analysis was a household that practiced small scale farming. The focus of the respondent was the household head or leader. When the head of the home was unavailable, a dependable family member was chosen to administer the questionnaire.

### 4.3 Sample Size

The sample size has been arrived at by using the Morgan and Krejcie (1970) formula which facilitates sample size computations calculated from a given predetermined population (P). The computation is such that the results are within a negative or positive value of 0.05 of the fraction of the P calculated to a confidence level of 95%. This procedure is described by the formula below

i) $$s = \frac{X^2 nP(1-P)}{d^2(N-1) + X^2 P(1-P)}$$

Where: ***s* =** Sample size

***N* =** size of population, in this instance **596,268** (Census, 2009)

***n*** = total number of households in Nyandarua County. in this instance **119,254**

***P* =** population ratio assumed as 0.5 to provide a maximum amount of samples

***d* =** degree of freedom in accuracy stated as 0.05

The formula gave a population sample size of 294 households as the number of respondents that may have been used. However, to minimise the error of non-reporting a larger sample size of 300 farmer's households was considered so as to cater for the non-responses.

## 4.4 Sampling Technique

The selection and choice of household was drawn using a multi-stage sampling technique which involved first choosing a ward within a sub county, then selecting the households using systematic sampling technique, which involved first randomly selecting a start point considering the most significant population of study and then locating succeeding constant intervals between the samples. The 10$^{th}$ small scale farmer household head followed the first small scale household head chosen in a location. If the 10$^{th}$ house hold head farmer was unavailable, the researcher selected the 11$^{th}$ one, and the process continued until a sample size of 300 respondents in the entire region was reached. The sample size was distributed in proportionately within the five sub-counties, as depicted in Table 4.1

**Table 4.1: The number of population samples in the distribution table**

| Sub-County | Region ($Km^2$) | Total Population | No. of households | No. of locations | Selected no. of households (n) | % of the total sample size |
|---|---|---|---|---|---|---|
| Ol'kalou | 586.7 | 120,282 | 24,056 | 21 | 61 | 20% |
| Ol'jororok | 389.1 | 95,643 | 19,129 | 8 | 48 | 16% |
| Ndaragwa | 653.6 | 92,626 | 18,525 | 13 | 46 | 15% |
| Kinangop | 822.0 | 192,379 | 38,476 | 16 | 97 | 33% |
| Kipipiri | 543.7 | 95,338 | 19,068 | 12 | 48 | 16% |
| Total | 2,995.1 | 596,268 | 119,254 | 70 | 300 | 100% |

Source: Census 2009

## 4.5 Primary data

The preferred data recording and collection method in the study area was questionnaires administered to select the small-scale farmers in the County. The questionnaires comprised of unstructured and structured questions and were administered to the five sub-counties selected farmers. Key informant interviews were conducted before and after compiling the first and second objectives using structured and unstructured interview guides. This is because in any research undertaking, the conclusions arrived at and the related recommendations largely depend on validating the data collected at the initial stages with the expert opinions collected at the end of the study.

### 4.5.1 Questionnaires

The household questionnaire administered in this study was a structured open and closed ended. These questionnaires were administered to small scale farmers per household. The questionnaires were compiled in three thematic sections: (1) Demographic characteristics and household biodata, (2) Climate variability and adaptation used by respondents, and (3) Socioeconomic characteristics of respondents. The research utilized questionnaires for economical data collection, enhancing reach and allowing participants to fill in without supervision. Physical questionnaires were also provided to farmers for offline access through research assistant.

### 4.5.2 Key Informant Interviews

In-depth talks with people chosen for their extensive understanding of an area of research are known as key informant interviews (Tremblay, 2009). Both structured and unstructured methodologies were used. The study used an interview guide for assurance that they would capture all relevant information. The interview was conducted before and after the compilation of the first and second objectives chapters of the study. Twenty key informants and resource persons were selected for the interview. The key informants and resource persons were purposively sampled to include the deputy director of agriculture-crops in Nyandarua County government, frontline extension officers, agricultural development officers and extension officers in the area. The researcher perceived them as knowledgeable of the past and current trends of climate variability, crop farming, and adaptations measures and strategies in Nyandarua County. The key informants' interviews were essential in compiling the recommendations for policymakers on climate variability and crop farming adaptation strategies derived from study objectives and findings.

### 4.5.3 Field observation and photographing

A brief pilot study or reconnaissance was conducted in one of the sub counties to familiarize with the area of study. During the reconnaissance, it was realized that some questions in the questionnaire were ambiguous and required clarity. It is from this pilot study that observation of crop farming techniques was found to be a vital source of primary data.

Observation would help to note the critical aspects of farming systems, climate phenomena, physical environment, and situations that people may not have revealed during the administering of questionnaires (Ngigi, 2009). During observation, photographs were captured to visually describe the present condition of farming and adaptations and capture the physical impressions of climate and weather variability on crop farming.

## 4.6 Secondary data

Secondary data refers to the second hand information gathered from sources like books, reports, articles, and surveys.

### 4.6.1 Maize and Irish potatoes output data

The study obtained the past statistical data for maize, and Irish potatoes yields and output from the Ministry of Agriculture statistics and County agricultural office.

### 4.6.2 Nyandarua County rainfall variation and temperature statistics

The data set included rainfall amount and temperature statistics and data measured in Millimetres and degrees Celsius respectively gathered during a 21-year span, or from 1999 to 2021. The monthly observed and recorded values of rainfall and temperatures values were acquired from the Kenya Meteorological Department and Nyahururu weather stations located at the Kenya Agricultural Research Institute within the County. To ensure that there was no climate data gap in the period of study that is from 1999 and 2019, the climate data collection involved a rigorous, meticulous and comprehensive process of verification, comparison and validation of the data obtained at Nyahururu weather substation with the KMD climate data abstracts.

## 4.7 Data analysis and presentations techniques

The statistical software package version 17 was used to analyze data. The data analysis techniques for the primary and the secondary data included the following;- Frequencies of Means, Percentages, Standard deviations and Coefficient of variance, Pearson Correlation and regression coefficients.

### 4.7.1 Mean, Standard deviation and Coefficient of variance

The parameters applied to determine the extent of temperature changes and rainfall variability were the mean, coefficient of variability (CoV), and linear regression. The annual averages required the calculations of monthly total rainfall, as well as monthly maximum and minimum values of temperatures.

ii) $$\textit{Annual Average Temperature} = \frac{\sum \textit{Mean Monthly Temperature}}{12\ (\textit{Number of Months})}$$

The mean annual rainfall is calculated by dividing the average monthly rainfall for each year by the number of months.

iii) $$\textit{Annual Average Rainfall} = \frac{\sum \textit{Monthly Rainfall Totals}}{12\ (\textit{Number of Months})}$$

To detect annual average rainfall and temperature trends across time, linear regression was used. The linearity of the slopes of the relevant regression lines were used to define the rate of change in a linear regression model (Karabulut et al., 2008). Due to rainfall seasonality, many missing monthly readings may affect the seasonal rainfall trend computation, influencing the averages by acting as extreme values. For this reason, the Pearson Correlation Coefficient was used to connect the coefficient of variation (CoV) with the output of maize and Irish potatoes after the yearly rainfall for the full time was calculated. Using the formula below, the CoV was computed by dividing the standard deviation of the rainfall by the mean.

iv) $\boldsymbol{Coefficient\ of\ variance} = \frac{\boldsymbol{Standard\ deviation}}{\boldsymbol{Mean\ annual\ rainfall}}$

The standard deviation statistic is a measurement of how far the data deviates from the mean value. It aids in the comparison of data sets that have the same Mean but distinct ranges. The standard deviation was calculated by subtracting the mean from monthly rainfall, adding it for n months, dividing by n, and then square rooting to obtain the standard deviation.

The formula given below is used to calculate the standard deviation.

v) $\boldsymbol{Standard\ Deviation\ (s)} = \sqrt{\frac{\sum_{i=1}^{n}(x_i - \bar{x})}{n-1}}$

Where;

$\sum$= Totality of individual values of $(x_i - \bar{x})$ for i - n (January to February)

n = Total sum of number of observations/values for12 months

$x_i$=Cumulative number of variables $x$

$\bar{x}$=Mean of the variable $x$

√=Square roots

The interpretation of CoV was that; the higher the CoV, the more the variability of the rainfall quantity of the location, and the lower the CoV the less variable the rainfall was for the entire period.

### 4.7.2 Pearson Correlation Analysis;

The study used the Pearson Correlation Coefficient to measure the specific climatic variables of rainfall and temperature relationships with yields for particular food crops in the entire period. The factors that might have affected the observed variance in the selected crop output were identified with the aid of this analysis. In order to ascertain the correlation between the individual climate variables of temperatures and rainfall amount and the yield of maize and Irish potatoes, the correlation coefficient (r) was utilized to produce a realistic numerical association between two variables.

The following formula computed the correlation coefficient;

vi) $$r = \frac{\sum_{i=1}^{N}(x_i - \bar{x})(y_i - \bar{y})}{\left[\sum_{i=1}^{N}(x_i - \bar{x})^2 (y_i - \bar{y})^2\right]^{1/2}}$$

Where;

$r$= The Pearson's Correlation Coefficient (r)

$\sum$= Summations of

$x_i$= Sum Total of variables $x$

$N$ = Sum Total observations

$y_i$= Sum Total of variables $y$

$\bar{x}$=Means of variables $x$

$\bar{y}$= Means of variables $y$

The student t-statistic test was applied to determine whether the correlation was significant at the 0.05 level of significance. Should the computed correlation value above the p-value, the null hypothesis would be rejected. In the event that the calculated correlation coefficient was less than the p- significance value, the null hypothesis was approved. Stated otherwise, a Pearson's (r) value near 1 indicates a potential high association in between the two elements, meaning that changes in one were likely to have significant effects on changes in the other. There was little to no correlation between the two statistical variables when Pearson's was near 0. A negative association implied that a positive change in one variable would probably result into a negative change in the other, as indicated by a Pearson correlation (r) of -ve.

### 4.7.3 Linear Regression Analysis

The variation of selected crop output due to selected climatic variations was determined by running a simple regression model using MS Excel where the crop output was the predicted outcome (dependent variable) against the climatic variables which were the independent variables. The regression analysis was reported in the form of adjusted regression value $R^2$, P significance value, and regression equation;

vii) $\boldsymbol{Y = \beta_0 + \beta_1 X_1 + \acute{\varepsilon}}$.

The regression value $R^2$ was analysed using a scale of 0-1 so as to measure and determine the levels of significance. When the $R^2$ value was equal to or greater than 0.5 (50%), the relationship was considered significant. On the other hand, when $R^2$ was less than 0.5, the relationship between the variables was considered insignificant.

### 4.7.4 Multiple Regression Analysis

In order to evaluate the climate variability effects and influence on crop output in totality and test the associated hypothesis, the multiple logistic regression analysis was undertaken where each of the crop output was regressed as a function of the selected climatic variables of this study which were mean annual rainfall ($x_1$), mean annual minimum temperature ($x_2$) and mean annual maximum temperature ($x_3$) (Table 4.7). Using a multiple regression equation, the analysis of multiple regression results were displayed as shown below;

viii) $\boldsymbol{Y = \beta_0 + \beta_1 X_1 + \beta_1 X_2 + \beta_1 X_3 + \acute{\varepsilon}}$, the multiple regression coefficient of variance ($R^2$) and the significance levels (P).

### 4.7.5 Multinomial Logistic Regression (MLR)

The study evaluated the significant link between the dependent variables (adaptation strategies under investigation) and the independent variables (demographic and socioeconomic characteristics) using multinomial logistic regression technique. The MLR was also used to evaluate the success and effectiveness of the adaptations strategies adopted by the small scale farmers in improving the crop yields or output. The Multinomial Logistic Regression, also known as Multinomial Regression, is a complex inferential statistic tool used to predict an outcome of a nominally dependent variable subjected to more than independent variables. It is an appropriate tool of analysis that allows a dependent variable with two or more possible categories to be included in the model. Multinomial logistic regression analysis predicts dependent variable outcome using continuous or nominal variables. Adaptation strategies included crop diversification, planting resistant/fast-maturing varieties, adjusting planting dates, and income diversification. The study assumed farmers could only adopt one strategy at a time. The coding of the adaptation strategy in SPSS was as follows; adopters =1, non-adopters =0.

Before subjecting the data to MLR, several tests were done to ensure that the data to be analysed fit the method. The following assumptions were made based on the preliminary tests to ascertain the validity of the data;

i) The dependent and independent variables were measured in nominal and treated as continuous data.

ii) The independent variables were assumed to be mutually exclusive with no multicollinearity, where two or more independent variables were not significantly correlated.

iii) To establish a linear association between the continuous independent variables and the dependent variable, the outliers were eliminated.

Before estimating the regression model, it was crucial to check the existence of multicollinearity from the explanatory variables. In order to ascertain these assumptions, the data was checked using the SPSS statistical tool.

The Multinomial Logistic Analysis model for including adaptation strategies, according to Magombo et al., (2011), specifies the link between the probabilities of selecting an adaptation given a set of independent explanatory variables. In this case, each adaptation strategy was regressed as a function of the selected socio-economic variables of the respondents, which were age (x1), gender (x2), size of land under cultivation (x3), levels of income (x4) and level of education (x5) among others. The test analyzed four adaptation strategies: crops diversification, new crop variety, adjusting planting dates, and income diversification, which were categorical and not ordered meaning they may be applied or not (Yes or No).

The independent variables for this test were the demographic and socio-economic factors which were also categorical.

ix) $\boldsymbol{Y\mathrm{i} = \beta 0 + \beta 1X1 + \beta 1X2 + \beta 1X3 + \beta 1X4 + \beta 1X5 \ldots + \acute{\varepsilon}\mathrm{i}}$,

**Where;**

- Yi = adaptation strategy (crop diversification, planting of new resistant/fast-maturing crop variety, adjusting planting dates, and income diversification).
- β0: is the y intercept
- Xi, where i = 1, 2, 3, 4, 5….n, are descriptive variables (Socio-economic factors)
- β1……βn: presents the equation slopes in the model.

The Multinomial regression output was presented in tabular formats of Goodness-of-Fit, model fitting information and parameter estimates tables. Multinomial logistic regression was the preferred design for evaluating the interrelationship between the categorical variable to more than one or two independent variables; by estimating the possibility of different outcomes of categorically distributed dependent variables given a group of unrelated variables, which may also have been categorical. In order to evaluate and assess the effectiveness of the adaptations strategies adopted by the small-scale crop farmers in increasing the crop yields or output using the model, the independent variable, in this case was whether the adaptation techniques and strategies were very effective, either effective, or not effective. Again, these predicted outcomes were categorical and not ordered. Conversely, the dependent variables were the four adaptation strategies, i.e., crops diversification, new crop variety, income diversification and adjusting the planting dates.

Reporting the multinomial regression results was achieved by mentioning the Log-likelihood intercept of the multinomial regression equation (Wald: Likelihood Odds Ratio), the multinomial regression coefficient of variance (B), The exponential values of the coefficients (Exp (B)), Marginal Effects (ME), Pseudo R-squared ($R^2$) and the significance levels (P). The two measures of regression were used to assess how well the model fitted the data. This assessment was provided by the Goodness-of-Fit table. Large chi-square values, i.e., more than 1000, indicated a poor model fit. The P-value indicated whether the model was significant or not in giving the results. The model fit the data well and was significant when P was less than 0.05. The model fitting information table presented whether all the coefficients were statistically significant to the model. Pseudo R-Square ($R^2$) was also used to predict the proportion of variance that the model could explain. Pseudo R Squared measures the variations between two or more independent variables whereby the variation is between Zero and One. Zero means no variation, while one means perfect variation. The parameter estimates tables presented the coefficients of the model.

To determine if an independent variable predicted the potential result of the dependent variable, the exponential values of the coefficients (Exp (B)) were taken into account.

## 4.8 Descriptive Statistics

Following data collection, recording, and analysis, it was prudent to represent the insight in a meaningful form for several users. This study presented data in tables, graphs, pie charts, and photographs. The correlations between two or more categorical variables were displayed using cross-tabulation statistics. This mode of statistics represented the values of the variables in tabular format with one variable determining the rows and the other producing the columns. Cross-tabulation tables are also referred to as contingency tables. They helped to understand the correlation between different variables. Cross tabulation is a descriptive statistic that summarizes the relationship between different variables of categorical data. The limitation of cross-tabulation tables is that it does not create any inferential statistics.

## 4.9 Research Ethics

Before starting the field research to gather the data, the researcher made sure they had all the necessary permissions from several authorities. These authorities were Local Chiefs and Assistant Chiefs (Public Administration), the County Government of Nyandarua, the University of Nairobi, and the National Commission for Science, Technology & Innovation (NACOSTI). The researchers made certain that the participants comprehended that the activity was optional and that any private information provided would remain private. Throughout the investigation, the researchers adhered to the ethics code by reporting truthfully and acting impartially when gathering, analyzing, and interpreting data.

# CHAPTER FIVE

# ASSESSMENT OF CLIMATE VARIABILITY AND CROP FARMING

## 5.1 Introduction

Based on the initial goal of evaluating the climate variability in mean annual rainfall and temperature and its impact on crop farming (maize and Irish potato output) in Nyandarua County, this section includes the analysis, interpretation, and discussion of the research findings. In order to fulfil the first goal, the researcher examined temperature variations and rainfall totals in Nyandarua County over a 21-year period, establishing a relationship between the two factors and the yield of two crops (Irish potatoes and maize). The mean, standard deviation, and coefficient of variance were used as descriptive statistics to analyze the climate's variability and the components of crop output. Regression analysis statistics and inferential correlation were employed to determine the association between the two meteorological conditions and the yield of the chosen crops. The two climatic factors' variability were determined by simple line trend and scatter graphs. The scale of scatter graphs is given at intervals of five years where the start year of 1999 can easily be traced as the point before 2000. A five year scale interval starts at 2005 and ends in 2020. At the same time, the hypothesis related to this research question and objective was analysed and tested based on the results and inferences of the regression and correlation analysis technique. The findings based on each outcome are discussed systematically later in the chapter. In conclusion, the chapter presents a brief conclusion of issues discussed and analysed regarding the first objective.

## 5.2 Rainfall amount variation and Temperature variability

The mean, standard deviation, and coefficient of variance were used as descriptive statistics to analyze the variability of the two climate parameters. The variance was determined by running a trend and scatter graph analysis where the climatic variables were distributed over 21 years. The variance results were presented in the form of a trend line and scatter graph. The Nyahururu meteorological station and the Kenya meteorological service provided secondary climate data for this investigation.

### 5.2.1 Nyandarua County's mean annual rainfall trend (1999-2019)

Table 5.1 presents descriptive information indicating that the average annual rainfall over the past 21 years was 1042.80 mm, with a standard deviation of 229.92. The mean annual range was 75, while the mean annual rainfall variance was 367.12. The yearly rainfall figures for the minimum and maximum were 672 mm and 1,572 mm, respectively.

**Table 5.1 Descriptive statistical data for rainfall amount in mm**

| Descriptive Statistics | Total annual rainfall | Mean annual rainfall |
|---|---|---|
| Mean | 1,042.80 | 86.9 |
| Standard Deviation | 229.92 | 19.16 |
| Maximum | 1,572.00 | 131.0 |
| Minimum | 672.00 | 56.0 |
| Variance | 52,864.70 | 367.12 |
| N | 21 | 21 |

Source: Researcher 2021

The study's other findings, as displayed in table 5.7, reveal that the annual mean rainfall increased between 1999 and 2006. But from 2007 to 2019, there was a significant range in the mean annual rainfall between high of 117.4 mm and off peaks of 67.1 mm. The last three years preceding the study (2017-2019) saw the area experience a steady rise in mean annual rainfall. However, some particular years between 1999 and 2019 registered very low mean annual rainfall, impacting reduced crop output in Nyandarua County. These low rainfall regimes include; the year 2000 (56.0mm), 2009 (59.1mm) and 1999 (65.5mm). In addition, the physical observation of the scatter graph presented below in figure 5.1 indicates that the highest rainfall fluctuation was experienced and recorded between 2007 and 2013. The mean annual rainfall between 2002 and 2007 supports Jaetzold et al.'s (2007) finding that rainfall patterns and intensity in central Kenya were slightly unpredictable.

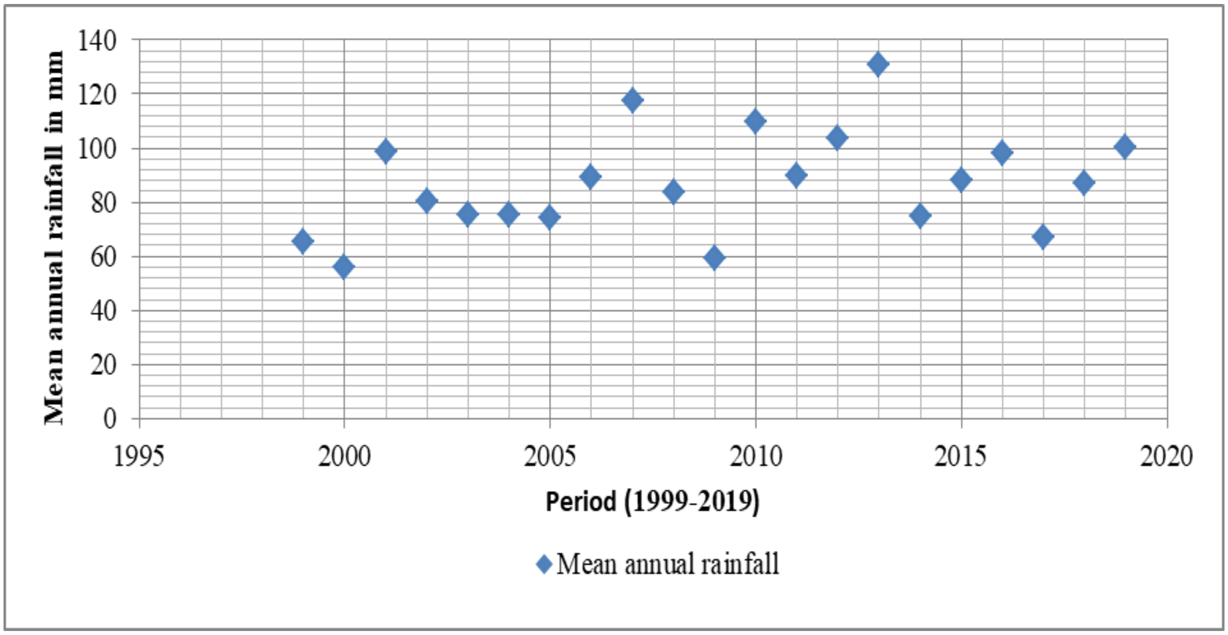



**Figure 5.1: A scatter graph of the trend of mean annual rainfall (1999-2019)**

Source: Researcher 2021

### 5.2.2 Trend of mean annual temperature in Nyandarua County (1999-2019)

Temperature changes were observed for 21 years in both annual and maximum temperatures. Descriptive statistics for these variables indicate that the lowest annual minimum temperature (7.5$^0$c) was recorded in 2004, while the annual average maximum temperature (24.0$^0$c) was recorded in 2000. The 21 years annual average minimum temperature was 8.52$^0$c, while the annual average maximum temperature was 22.21$^0$c. Table 5.2 below compares more descriptive statistics related to this variable.

## Table 5.2 Descriptive statistics for temperature in $^0$c

| Descriptive Statistics | The annual average minimum temp. in $^0$c | Annual average maximum temp. in $^0$c |
|---|---|---|
| Mean | 8.52 | 22.21 |
| Standard Deviation | 1.23 | 1.05 |
| Variance | 1.48 | 1.09 |
| Minimum | 7.50 | 20.40 |
| Maximum | 11.60 | 24.60 |

Source: Researcher 2021

The trend analysis for this variable in figure 5.2 indicates that variation in minimum annual temperature was much higher than in maximum annual average temperature. These results were further elaborated in line graphs which presented variations of annual average temperature across the 21 years between 1999 and 2002. There was a continuous rise in both maximum and minimum temperatures uniformly. A drop of 3$^0$c followed this in both temperatures between 2002 and 2003. From the year 2003 to 2019, the temperature did not change significantly.

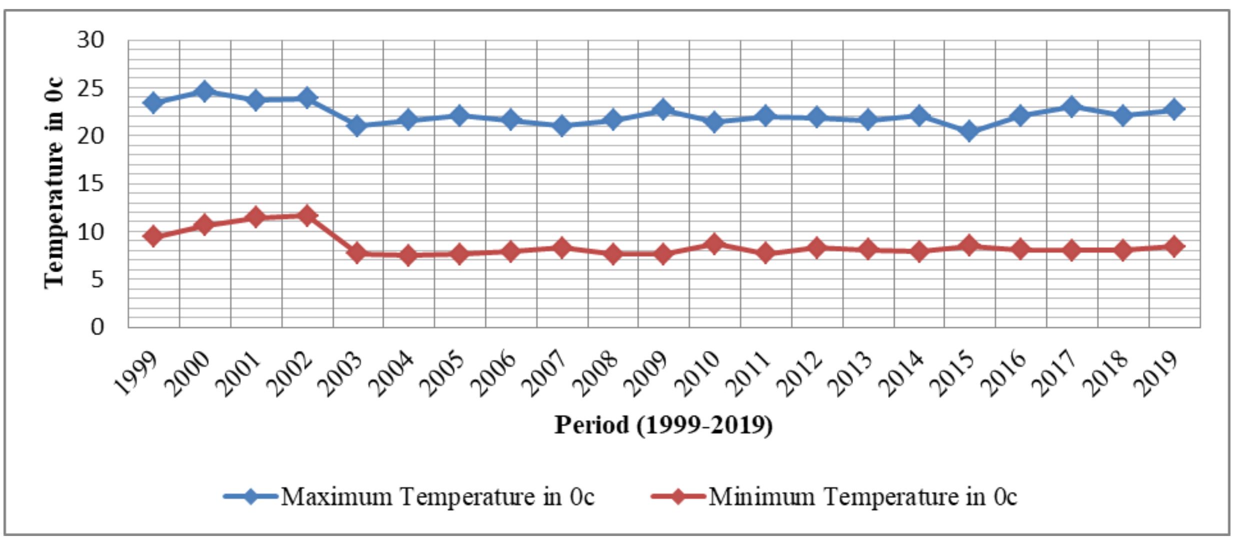



**Figure 5.2: A line graph showing the trend of mean annual minimum and maximum temperature (1999-2019)**

Source: Researcher 2021

## 5.3 Maize and Irish Potato output variability

The study analyzed the variability of the two crop output elements using descriptive statistics of mean and standard deviation. The variance was determined by running a trend and scatter graph analysis where the crop output variables were distributed across the 21 years (1999-2019). The results of this variance were presented in the form of the trend line and scatter graphs. Secondary crop output data was obtained from Nyandarua County Government, department of agriculture.

### 5.3.1 Variation and trend of maize output in Nyandarua County

The County government of Nyandarua provided the data, which was based on 21-year annual crop output analyses. It showed that, between 1999 and 2019, maize output averaged 29,145.76 tonnes, with a maximum of 54,951 tonnes recorded in 2011 and a minimum of 10,343 tonnes recorded in 2000. There was a noticeable decrease in the amount of maize produced between 2013 (53,575 tonnes) and 2014 (10,343 tonnes). Rainfall was also highest in 2013 (131mm), followed by a sudden drop in 2014 (74.9mm). This relationship indicates a positive correlation between rainfall amount and the output of maize between these two periods. However, a detailed observation revealed that in 2011 when the annual rainfall was 1080mm with a mean of 90mm, produced the highest maize crop output of 54,951 tonnes. This result showed that crop productivity was not always maximized by maximum rainfall. Perhaps the maximum output of maize could have been attributed to by effective application of proper adaptation strategies. This finding was also noted by Adam et al. (2020), whose findings revealed that climatic factors could not sustain high crop yields alone unless accompanied by proper adaptation measures. In addition, the adaptation techniques and measures employed by the small scale farmers during this period could have improved the crop output despite a drop in the amount of rainfall. This finding calls for proper assessment of the small scale farmers' adaptation strategies for sustainable crop output amid the observed climatic variation.

The scatter graph for this variable in figure 5.3 indicates that there was a significant variation in maize output for 21 years. This variation in output created the need to investigate possible causes, i.e. the adaptation strategies that have so far been applied and to come up with possible solutions to maintain the stability in maize output.

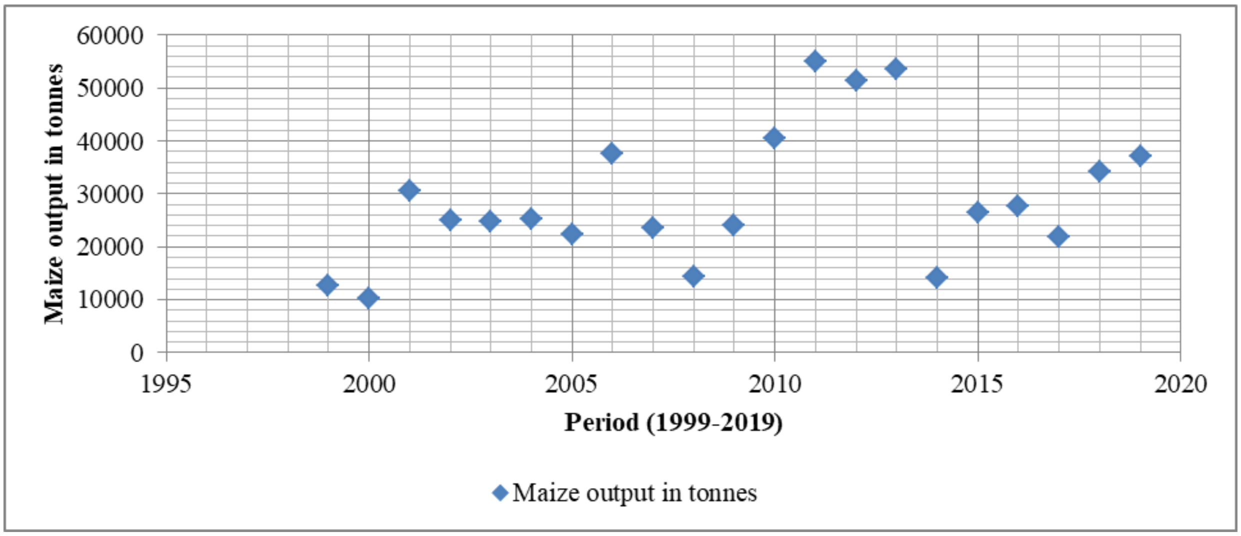



**Figure 5.3: A scatter graph showing the variation of maize output in tonnes (1999-2019)**

Source: Researcher 2021

### 5.3.2 Variation and trend of Irish potatoes output in Nyandarua County

Regarding this variable, the study indicates that Irish potato output increased between 2009 and 2019, as shown by the scatter plot in figure 5.4. The annual trend of Irish potato output was noticed to have increased as the quantity of output varied over the years. The average output of Irish potatoes was found to be 382,789.43 tonnes. Irish potatoes' mean output was 13 times more than the mean output of maize. This comparison of the means indicates that the Irish potato was a dominant crop in Nyandarua County. The high output could have resulted from favourable ecological conditions and the fact that it takes less time to mature than maize. The maximum output of Irish potatoes (1,145,995 tonnes) was recorded in 2011, while the minimum output (84,700 tonnes) was recorded in 2008. The increasing output trend in Irish potatoes was also noted in a study by Karanja (2013) in the Ol-jororok division in Nyandarua County.

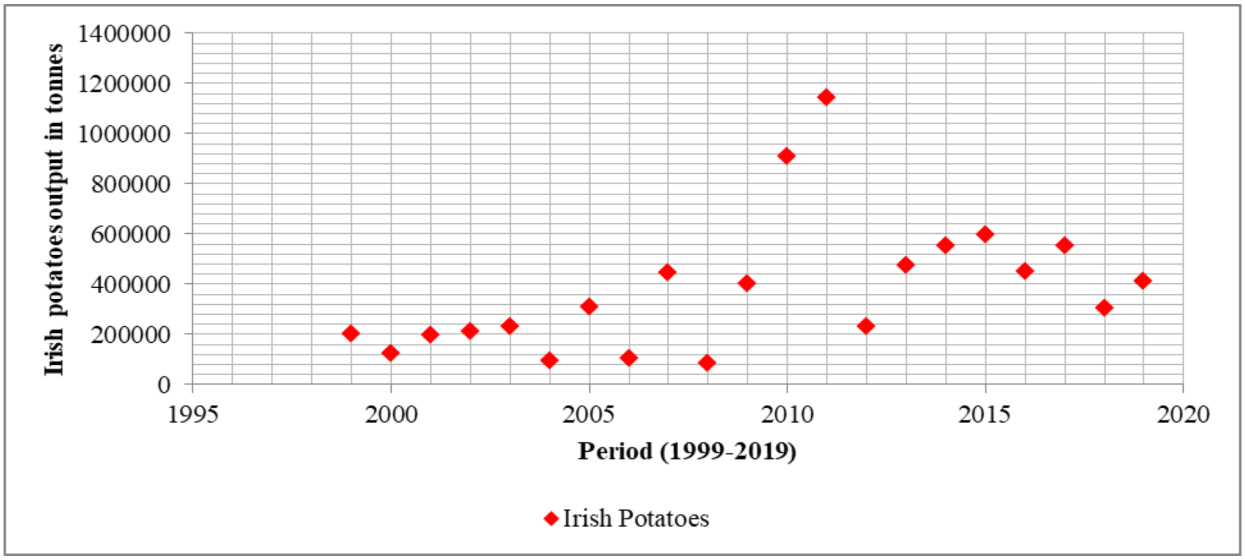



**Figure 5.4: A scatter graph showing the variation of Irish potatoes output in tonnes (1999-2019)**

Source: Researcher 2021

### 5.4.1 Rainfall variability and selected crop output

Analysis of these two groups of variables using comparative line graphs revealed some observable relationships between them. For example, between 1999 and 2000, a decrease in the mean annual rainfall was associated with a decrease in maize and Irish potato output. Between 2000 and 2001, there was a significant rise in mean annual rainfall, which collaborated with a significant rise in maize and Irish potato output. Between 2002 and 2005, the mean annual rainfall was relatively stable and likewise was the output of the maize crop. Between 2013 and

2014, mean annual rainfall decreased significantly from 131mm to 74.9mm, while maize output fell sharply from 53,575 tonnes to 14,017 tonnes. The last three years preceding the study showed a significant increase in rainfall.

Consequently, a significant increase in crop output, especially maize, was recorded. A further observation of the comparative graphs, however, presented a situation where the rainfall variability was related to the variability of maize much more than the Irish potatoes. More research may be carried out to establish the cause of this relationship.

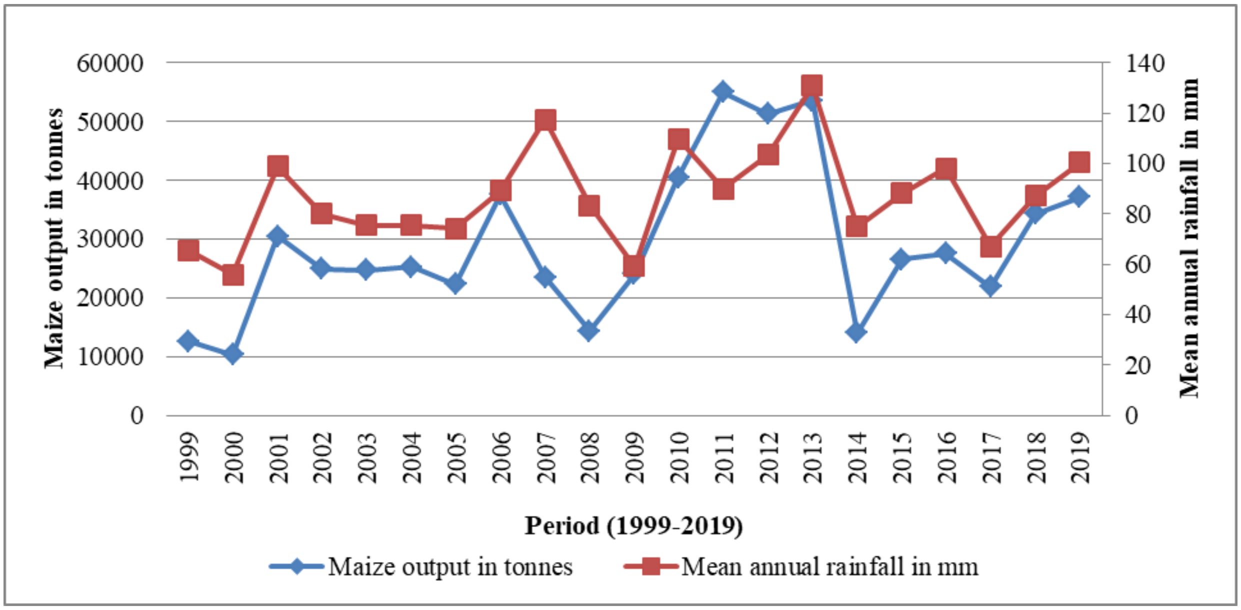



**Figure 5.5: A comparative line graph showing the trends of mean annual rainfall and maize output in tonnes**

Source: Researcher 2021

The aforementioned graphic demonstrates how rainfall and maize crop output were positively correlated in numerous years throughout a 21-year period. However, other agronomic factors, such as an increase in the area that could be farmed, a decrease in pests incidence and diseases, or even a decrease in post-harvest losses, could have contributed to the inverse relationship relating the factors of rainfall and maize output in the years 2007 and 2011, where an increase in rainfall did not correlate with an increase in maize output. The Kenya's Seed Company (2013) states that appropriate adaptation tactics have moderated other agronomic parameters and favourable meteorological conditions are necessary for successive maize production.

In this case, rainfall alone may not guarantee optimum production of maize. Indeed no other crop utilizes sunlight more effectively than maize (Du Plessiss, 2003). The average output of maize on any farm is said to be the product of climate and soil. Schroeder et al. (2013) suggest that the optimal soil for maize is one with adequate depth, favorable morphological properties, proper nutrients, good internal drainage, and optimal moisture, optimal rainfall potentially influencing maize output.

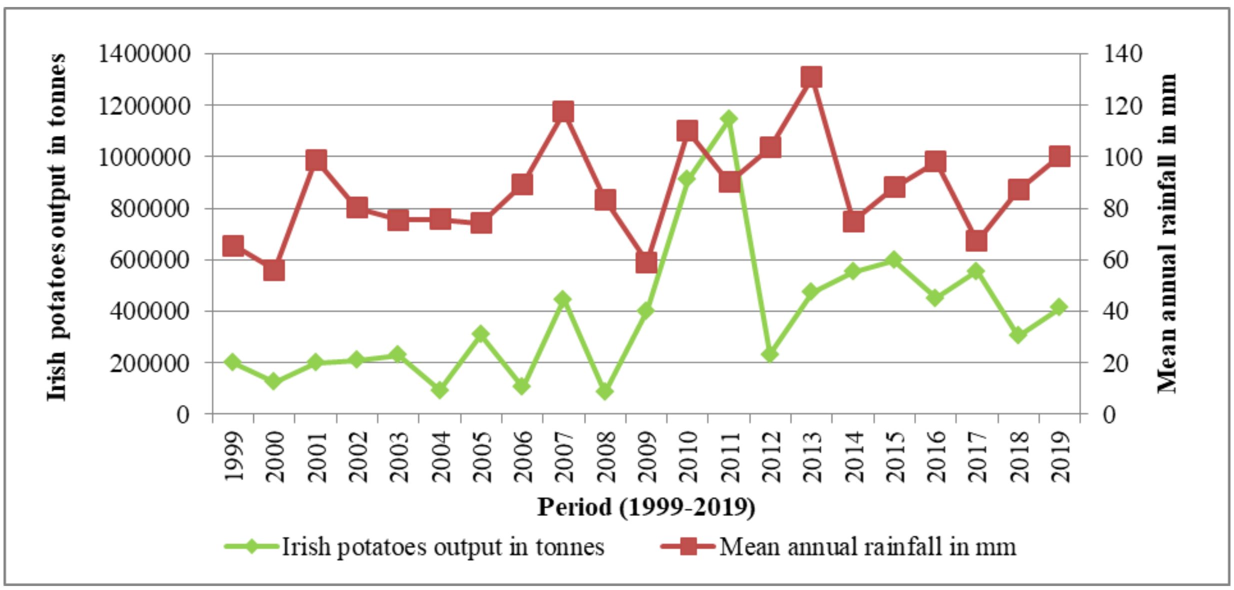



**Figure 5.6: A comparative line graph showing the trends of mean annual rainfall in mm and Irish potatoes output in tonnes**

Source: Researcher 2021

From the above figure 5.6, it can be seen that in most of the years between 1999 and 2019, a change in rainfall amount correlated positively with a change in Irish potato output. However, a few years recorded an opposite correlation, i.e. 2010, 2011 and 2019. This inverse correlation perhaps resulted from changes in seasons, temperature variations, and changes in the proportion of cultivatable land or probably a change in pests and incidence of diseases or even variations in after-harvest losses. However, an in-depth investigation of the causes of this relationship was not done since it was not within the scope of the study. Therefore, the cause for this inverse relationship creates a gap that can be investigated in further studies and subsequently generate new knowledge in this field of research.

### 5.4.2 Temperature variability and selected crop output

The highest and lowest temperatures are crucial in the growth and development of many food crops, especially in the equatorial region. Most crops in Kenya do well at optimum temperatures. Analysis of this variable with the selected two food crops using a comparative line graph presented a different scenario. The two food crops under examination and variations in the mean annual maximum and lowest temperature showed negligible apparent correlations. It was predicted that crop yield would be significantly reduced if temperatures rose above the optimal range. A temperature drop that is more than ideal would likewise cause a notable fall in crop yield.

Based on the comparative graphs presented in this study, it was concluded that temperature change is a less predictor of the variability of crop output than rainfall amount variability. This conclusion is one the new knowledge generated by the study. Smit et al., (2000) found that a significant rise in mean temperature beyond a threshold may cause a decrease in agricultural output.

Figure 5.7 indicated a sharp rise of Irish potato output between 2009 and 2011 even when the temperatures did not change significantly. There was not enough data to explain this unusual trend but perhaps other factors such as proper land management, introduction of new species and reduction in postharvest losses may have contributed to this sharp rise.

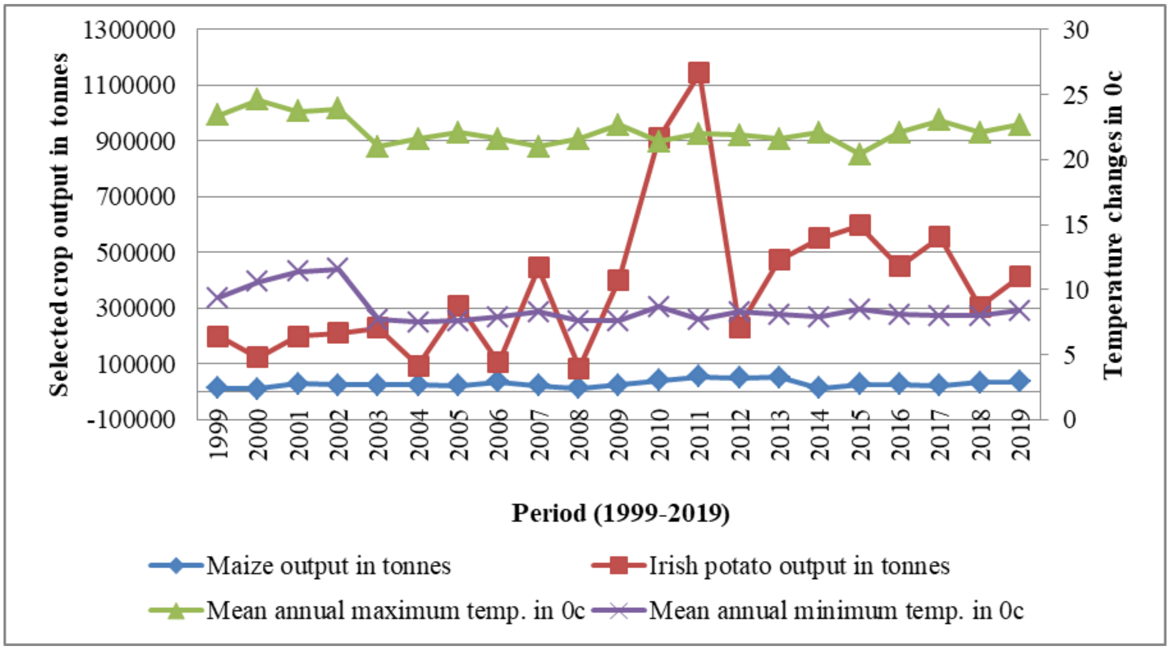



**Figure 5.7: Comparative line graphs of mean annual maximum and minimum temperatures in $^{0}$c and selected crop output in tonnes**

Source: Researcher 2021

### 5.4.3 Pearson Correlation between climate variability and crop output;

The researcher used secondary rainfall and crop output data from the KMD and the County Agricultural Statistics Office to establish the association between rainfall variability and crop output (Maize and Irish potatoes) in order to evaluate the influence of rainfall variability on crop farming. The Pearson correlation inferential statistics were used to measure this relationship. The output of this analysis was the correlation coefficient (r) used to critically establish the extent of relationships between the two absolute variables. The strength of the relationship was measured using a scale of 0 to 1. In other words, when Pearson's value of correlation was near 1, there was a strong relationship between the two investigated variables suggesting that a change in one variable was strongly linked to a change in the 2$^{nd}$ variable. There was little association between the two related variables when Pearson's correlation value was near to 0. A negative association implied that a positive change in one variable would probably result into a negative change in the other when Pearson's correlation value was –ve. The student t-test statistic was used to determine whether the connection was significant at the 0.05 significance levels. The null hypothesis was rejected if the correlation value that was found was greater than the p-value of 0.05. In the event that the computed correlation value (r) was smaller than the p-value, the null hypothesis was accepted.

**Table 5.3: Summary table for Pearson correlation values between rainfall and temperature variability and the selected crop output**

| **Correlations;** | | Annual Average Rainfall in mm | Annual Average Minimum Temp. in $^0$c | Annual Average Maximum Temp. in $^0$c |
|---|---|---|---|---|
| Maize Output | Pearson's Correlation | **.687****  | **-.187** | **-.316** |
| in Tonnes | Sig. (2-tailed test) | .001 | .417 | .163 |
| | N | 21 | 21 | 21 |
| Irish Potatoes | Pearson's Correlation | **.296** | **-.241** | **-.284** |
| Output in | Sig. (2-tailed) | .193 | .292 | .212 |
| Tonnes | N | 21 | 21 | 21 |

**. When using a two-tailed test, correlation is significant at 0.05 levels.

Source: Researcher's computations 2021

For the 21 years (1999–2019), a correlation analysis between rainfall variability and maize yield was conducted. Between the two variables, the Pearson correlation coefficient was 0.687. Given that the Pearson correlation value was near to 1 and greater than the p-value of 0.05, there was clearly a substantial positive association between the two dependent and independent variables. This was interpreted to mean that rainfall variability greatly influenced the variation of maize output within 21 years. This means there was enough evidence to reject the hypothesis ($H_0$) which stated that rainfall variability had not significantly impacted crop farming (maize output) in Nyandarua County. Likewise, the Pearson correlation coefficient value between rainfall variability and Irish potato output was $r$ =0.296. The co-efficient value was larger than the p-significance value of 0.05 but close to 0, which meant a weak positive significant relationship between the two study variables. This was interpreted to mean that rainfall variability less influenced the variation in Irish potato output within 21 years.

The minimum temperature variations and maize yield had a 0.187 Pearson correlation coefficient. There was a weak negative association between the variables under investigation, as indicated by the negative Pearson correlation value that was close to zero and bigger than the p-value of 0.05. This was interpreted to mean that minimum temperature variability less influenced the variation of maize output within 21 years negatively. This means that a slight rise in minimum temperature contributed to an insignificant decrease in maize output as well as the opposite. Likewise, the Pearson correlation coefficient value between minimum temperature variability and Irish potato output was $r = -0.241$. There was a weak negative association relating the two variables, as indicated by the negative Pearson correlation value that was close to zero and bigger than the significance p-value of 0.05. This also meant that a rise in minimum temperature was linked to an insignificant decrease in Irish potato output and likewise the other way round. These two relationships were therefore considered insignificant.

The Pearson correlation coefficient value between maximum temperature variability and maize output was $r = -0.319$, as shown in table 5.3. This Pearson correlation value was larger than the significance p-value of 0.05 but in a negative direction and close to zero, which means there was also a weak negative association between the two variables. This was interpreted to mean that maximum temperature variability influenced less negatively the variation of maize output within 21 years. This means that a rise in maximum temperature resulted in a decrease in maize output and vice versa. Likewise, the Pearson correlation coefficient value between maximum temperature variability and Irish potato output was $r = -0.284$. This correlation statistic was larger than the p- significance value of 0.05 but in a negative direction and close to 0, which meant a weak negative significant relationship amongst the two factors. This means that a slight rise in maximum temperature resulted in a slight decrease in Irish potato output and the opposite as well.

## 5.5 Linear Regression Analysis of climate variability and selected crop output

The variation of selected crop output due to selected climatic variations was determined by running a simple regression model using MS Excel, where the crop output was the predicted outcome (dependent variable) against the climatic variables that were the independent variables. The regression analysis was reported in the form of adjusted regression value $R^2$, P significance value and regression equation $Y = \beta_0 + \beta_1 X_1 + \acute{\varepsilon}$. The regression value $R^2$ was analysed using a scale of 0-1 to measure and determine the significance level. The relationship was regarded significant when the $R^2$ value was equal to or greater than 0.5 (50%). On the other hand, when $R^2$ was less than 0.5, the relationship between the variables was considered insignificant.

The variation results were presented in the form of a trend line graph, scatter graph and the slope of the regression equation. The regression analysis as an inferential statistic was used to partially test how much rainfall variations and temperature changes resulted in significant changes in selected crop output.

## Table 5.4: Model Summary for Linear regression analysis

| Model Variables | Model (Regression equation) | R | R Square | Adjusted R Squared | Std. Error | Df | F | P |
|---|---|---|---|---|---|---|---|---|
| Rainfall amount and Maize output | y= 463x - 11101 + έ. | 0.6869 | 0.4718 | 0.4440 | 9633.42 | (1, 19) | 16.97 | 0.0006 |
| Rainfall amount and Irish potatoes output | y=4159.5x+21330 + έ | 0.2958 | 0.0875 | 0.0395 | 264044.2 | (1, 19) | 1.82 | 0.19 |
| Maximum temperature and Maize output | y=-3907.4x+115945 + έ | 0.3161 | 0.0999 | 0.0525 | 12575.26 | (1, 19) | 2.11 | 0.16 |
| Minimum temperature and Maize output | y=-1984.4x+46051 + έ | 0.1870 | 0.0349 | -0.0159 | 13021.29 | (1, 19) | 0.69 | 0.42 |
| Maximum temperature and Irish potatoes output | y=-73286x+2010790 + έ | 0.2843 | 0.0808 | 0.0324 | 265009.3 | (1, 19) | 1.67 | 0.21 |
| Minimum temperature and Irish potatoes output | y=-53420x+837876 + έ | 0.2413 | 0.0582 | 0.0086 | 268249.16 | (1, 19) | 1.17 | 0.29 |

Source: Researcher's computations 2021

### 5.5.1 Rainfall variability and selected crop output-Linear Regression Analysis

Equation $Y$ = 463x - 11101 + α described the nature of the slope of the regression line of rainfall variability and maize yield. Rainfall was responsible for 47.18% of the variation in maize yield, according to the regression value of $R^2 = 0.4718$. The Coefficient of variance test, F (1, 19) = 16.97, P = 0.0006, indicates that rainfall variability significantly contributed to changes in maize crop output. This is because the regression value $R^2 = 0.4718$, having been rounded off to a whole number, indicated that rainfall variability significantly contributed to 50% of changes in maize crop output. In this case, there was considerable evidence of rejecting the null hypothesis associated with this variable.

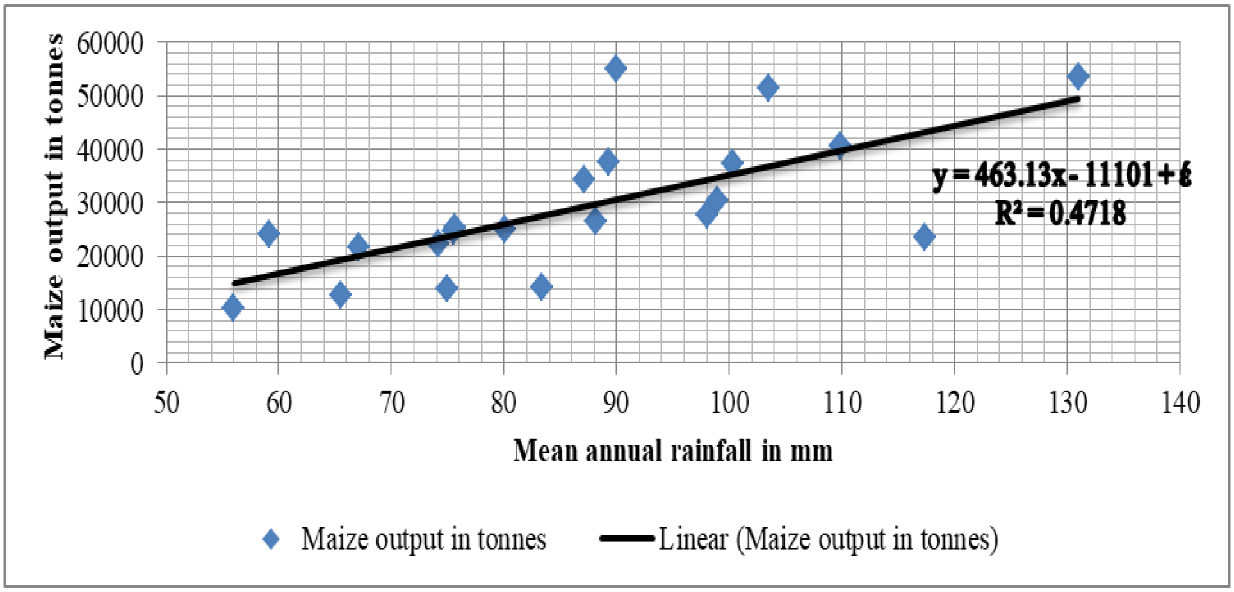



**Figure 5.8: A scatter graph showing the variation in maize output due to mean annual rainfall (1999-2019) and the slope of linear regression analysis**

Source: Researcher 2021

The linear regression line for Irish potatoes output and mean annual rainfall produced the linear equation of y=4159.5x+21330 + ἑ and regression value $R^2$=0.0875. These results indicate that rainfall variability resulted to an 8.75% variation in Irish Potato output. These tests were not statistically significant at P=0.19, which is more than the significance level of 0.05. However, the relationship of the two variables given by $R^2$ = 0.0875 indicates that there was no significant relationship and, therefore, there was no evidence to discard the null hypothesis. This is because rainfall variability alone could not explain 91% of the variation in Irish potato output.

The null hypothesis that rainfall variability did not influence the variability of Irish potatoes failed to be rejected. This implied that factors other than rainfall greatly influenced potato crop farming and subsequent output. Agronomic factors such as morphological properties of soils, proper application of fertilizers, pest and disease control, change in the size of cultivable lands, management of losses after harvests, etc., have a greater influence over the production of Kenya's main crops.

These results further indicate that variation in maize output was much higher due to variation in rainfall than the output of Irish potatoes. These results were similar to the findings of Mikalitsa (2010), where climate variability as manifested by rainfall unreliability and prolonged drought was among the top possible cause of reduced crop output in Kenya. The results though differed significantly in terms of variance, where the current study variation of 8.75% in Irish potato output due to rainfall was minimal. Perhaps other major agronomic and socio-economic factors, including some adaptation strategies greatly influenced the output of Irish potatoes in the study area. These factors may range from changes in seasons, temperature, cultivable land size, pest reduction, diseases, and after-harvest losses which can impact agricultural production.

This finding concurred with a study by Masabnni, J. (2009), which indicated that differences in Irish potato tuber development were not significantly related to changes in soil moisture due to rainfall variations. This is because high rainfall accompanied by hot weather leads to the breakage of tubers. In addition, too much water enlarges the pores on the tubers and makes them rot quickly. This effect ultimately results in reduced Irish potato crop output.

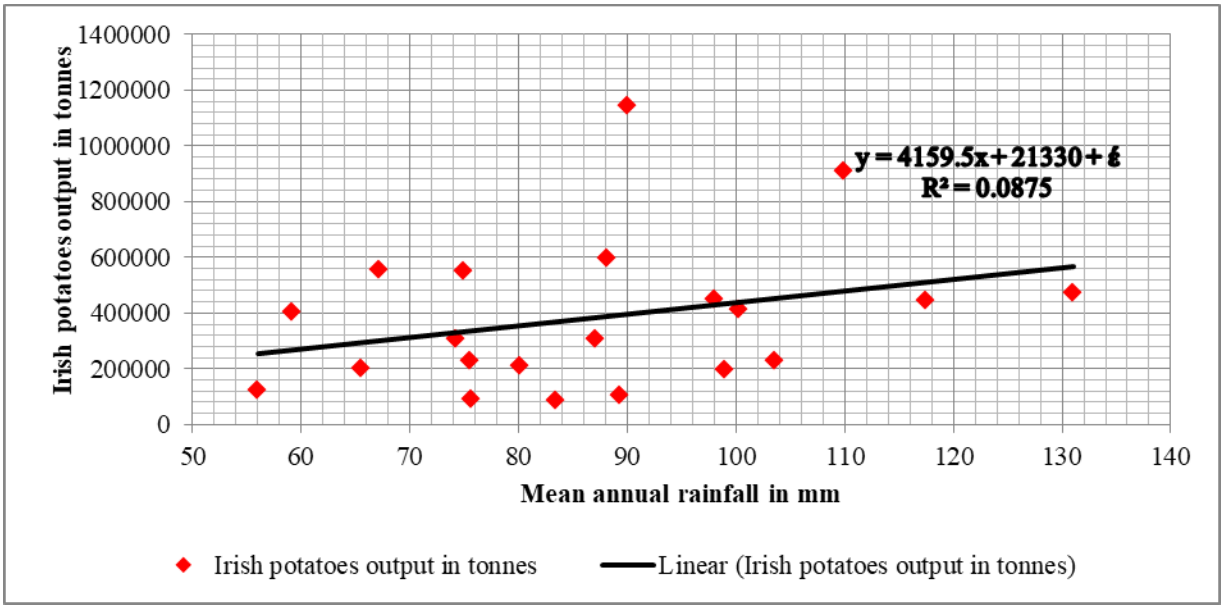



**Figure 5.9: A line graph showing the trend of Irish Potatoes output against mean annual rainfall (1999-2019) and the slope of linear regression analysis**

Source: Researcher 2021

### 5.5.2 Temperature variability and maize output - Linear Regression analysis

The linear regression analysis of maize output and mean annual maximum temperature was explained by the equation y=-3907.4x+115945 + ἐ. The linear regression value of $R^2$=0.0999 indicates that 9.9% variation in maize output was due to variation in maximum temperature. Perhaps other major agronomic and socio-economic factors, including some proper crop-related adaptation strategies, greatly influenced the output of Irish potatoes. These factors may range from changes in seasons, temperature, cultivable land size, pest reduction, diseases, and losses following harvest which can impact agricultural production.

The Coefficient of variance test, F (1, 19) =16.97, P=0.16, indicates that the maximum temperature variability did not significantly contribute to changes in maize crop output. This sample did not provide enough evidence for rejecting the null hypothesis. Regarding mean annual minimum temperature, the linear regression analysis of maize output was defined by the equation y=-1984.4x+46051 + ἐ. The regression value of $R^2$=0.0349 indicates a 3.5% variation in maize output due to variation in minimum temperature. The Coefficient of variance test, F (1, 19) = 0.69, P= 0.42, indicates that the minimum temperature variability did not significantly contribute to changes in maize output. This sample did not provide enough evidence for rejecting the null hypothesis.

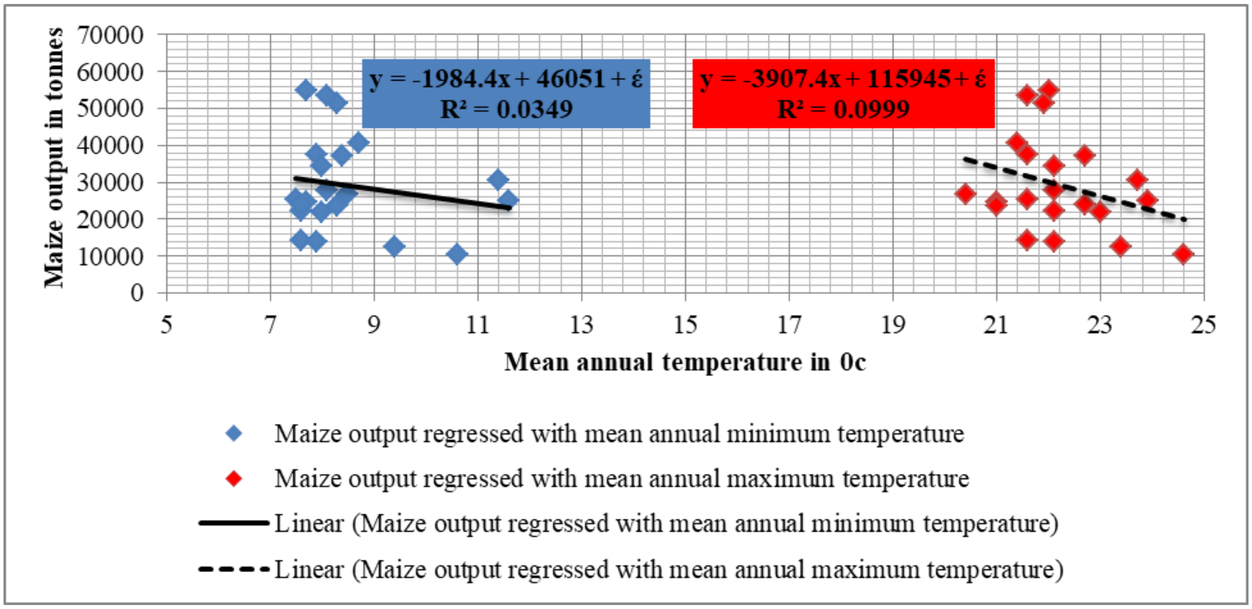



**Figure 5.10: Scatter graphs showing the variation in maize output due to mean annual minimum and maximum temperatures changes (1999-2019)**

Source: Researcher 2021

### 5.5.3 Temperature variability and Irish potatoes crop output- Linear Regression analysis

The linear regression analysis of Irish potatoes output and mean annual maximum temperature was defined by the linear equation y=-73286x+2010790 + ἐ. The regression $R^2$=0.0808 indicates an 8.1% variation in Irish potato output due to variation in maximum temperature. The Coefficient of variance test, F (1, 19) =1.67, P=0.21, indicates that maximum temperature variability did not significantly contribute to changes in Irish potato output. This sample did not provide enough evidence not to accept the null hypothesis. Concerning mean annual minimum temperature, the linear regression analysis of Irish potato output was described by the linear equation $y=-53420x+837876 + έ$. The regression value of $R^2=0.0582$ indicates a 5.9% variation in Irish potato output due to variation in minimum temperature. The Coefficient of variance test, $F (1, 19) = 0.69$, $P= 0.42$, indicates that the minimum temperature variability did not significantly contribute to changes in Irish potato output. This sample also did not provide enough reason of rejecting the null hypothesis. These results however contradicted the findings of Ojwang et al, (2011). They revealed that a change in the least temperature is more significant in crop output than a change in the maximum temperature. The optimum temperature range for Irish potatoes is from $16^0$c to $20^o$c (Kenya Seed Company, 2013). Temperatures above $32^o$c result in poor Irish potato tuber initiation, while shallow temperatures result in frost action that is too sensitive to Irish potato plants (Schroeder et al., 2013).

In Nyandarua County, the highest output of Irish potatoes was achieved at a minimum temperature of $7.7^0$c and $8.7^0$c and a maximum temperature of between $21.9^0$c and $22^0$c. The minimum temperature for the entire period was between $7.5^0$c and $11.6^0$c. Likewise, the maximum temperature recorded for the entire period was between $20.4^0$c and $24.6^0$c. These two indicators illustrate that Nyandarua County attained the optimum temperature for maximum Irish potato production. However, the freezing and low temperatures experienced perhaps impacted the crop output negatively due to the incidence of frostbite.

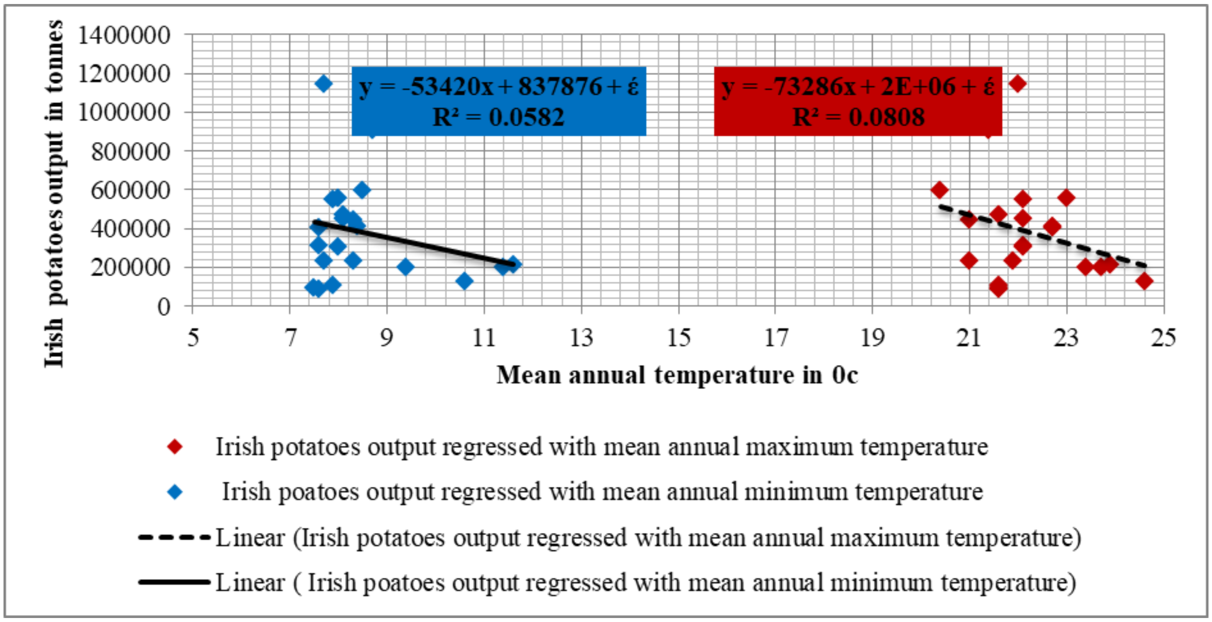



**Figure 5.11: Scatter graphs showing the variation in Irish potatoes output due to mean annual minimum and maximum temperatures changes (1999-2019)**

Source: Researcher 2021

## 5.6 Using the Multiple Regression Analysis to assess the impact of temperature variations and rainfall changes on crop output

To evaluate the overall effect of climate variability on specific crop productivity and verify the related hypothesis, a multiple regression analysis was carried out where each crop output was regressed as a function or element of the selected climatic variables of the study which were the mean annual rainfall ($x_1$), mean annual minimum temperature ($x_2$) and mean annual maximum temperature ($x_3$) (Table 5.7). The results of the multiple regression analysis have been presented in the form of the multiple regression equation $Y = \beta_0 + \beta_1 X_1 + \beta_1 X_2 + \beta_1 X_3 + έ$, the multiple regression coefficients of variance ($R^2$) and the significance levels (P). The results and interpretation of the multiple regression statistical analysis was used to test the hypothesis for the first objective in totality.

### 5.6.1 Multiple regression analysis for maize output as a function of rainfall changes and temperature variations

The multiple regression analysis for this association gave the following results in table 5.5:

**Table 5.5: Multiple regression analysis model summary (1)**

| Model (Regression equation) | (R) | R Squared | Adjusted R Square | Std. Error of the Estimate | Df | F | P |
|---|---|---|---|---|---|---|---|
| $y=-71821.86+546.85x_1-3891.65x_2+3898.36x_3+\varepsilon$ | 0.73 | 0.53 | 0.44 | 9648.69 | (3,17) | 6.29 | 0.005 |

a. Predictors: Rainfall, Minimum and Maximum Temperature changes

b. Dependent variable: Maize output in tonnes

Source: Researcher's computations 2021

The above table shows the results of the multiple regression where maize crop output was regressed as a function of the selected climatic variables of this study which were the mean annual rainfall ($x_1$), mean annual minimum temperature ($x_2$) and mean annual maximum temperature ($x_3$) (Table 5.5).

From the above results, it was interpreted that 53% of the variation in maize output resulted from the combined climatic factors used in this study. The findings indicate that the P-value of 0.005 was less than the established significance level of 0.05, and the test was statistically significant. In this case, it was concluded that there wasn't enough evidence for rejecting the null hypothesis. Therefore the null hypothesis that rainfall and temperature variability had not significantly impacted crop farming (maize crop output) in Nyandarua County was rejected. Considering the fundamental crop performances in Kenya, Wambua et al. (2018) also concluded that maize has been the most negatively affected crop in the last two decades by climate variability. Other similar studies have documented that the trend of crucial crop productivity in Nyandarua County has either been stable or declining over the years occasioned by climate variability where rainfall patterns have changed. Temperature levels have increased beyond optimum or too low to cause frostbite (Mburu B.K., 2013; Mwaura J.M., 2015; Limo W.K., 2013).

### 5.6.2 Multiple regression analysis for Irish potatoes output as a function of temperature and rainfall variability

The multiple regression analysis for this association gave the following results in table 5.6:

**Table 5.6: Multiple regression analysis model summary (2)**

| Model (Regression equation) | (R) | R Square | Adjusted R Square | Std. Error of the Estimate | Df | F | P |
|---|---|---|---|---|---|---|---|
| $y=373003.53+4092x_1-52726.9x_2+4654x_3+\varepsilon$ | 0.37 | 0.14 | -0.01 | 271246.71 | (3,17) | 0.91 | 0.457 |

a. Predictors (Independent variables): Rainfall, Minimum and Maximum Temperature changes
b. Dependent variable: Irish potatoes output in tonnes

Source: Researcher's computations 2021

The above table shows the results of the multiple regression where Irish potatoes crop output is regressed as a function of the selected climatic variables of this study which are mean annual rainfall ($x_1$) and mean annual maximum temperature ($x_3$) and mean annual minimum temperature ($x_2$) (Table 5.6).

From the above results, it was interpreted that only 14% of the variation in Irish potato output resulted from the climatic factors used in this study. The results indicate that the P-significance value of 0.457 was more significant than the established significance levels of 0.05, and therefore the test was not statistically significant. In this case, it was concluded that there was not enough evidence to reject the null hypothesis. Therefore the null hypothesis that rainfall and temperature variability had not significantly impacted crop farming (Irish potatoes crop output) in Nyandarua County failed to be rejected. According to the results, this implies that the climatic variables used in this study did not influence the output of Irish potatoes significantly, unlike maize output. Therefore perhaps there were other major agronomic and socio-economic factors, including some proper crop-related adaptation strategies, which greatly influenced the output of Irish potatoes. These factors may range from changes in seasons, temperature, cultivable land size, pest reduction, diseases, and postharvest losses which can impact agricultural production. This illustration creates a gap that can be investigated in further studies.

### 5.7.1 Respondent's perception of the recent change in rainfall intensity

Regarding rainfall intensity, the researcher sought to get the state of understanding and awareness of climate variability by the small scale farmers. In order to do this, the researcher included two closed-ended questions in the questionnaire: (a) how much rainfall had changed over the last 10 years, and (b) whether respondents had observed any fluctuation or changes in rainfall during the recent years prior to the study. Overall, 93% of participants reported having noticed variations in rainfall in the years before the research, whereas 6% did not report any such observations. Subsequent investigation revealed that 214 (71.3%) of the 300 respondents said they had seen less rainfall. About 68 (22.7%) observed that rainfall amount had increased, while 18 respondents (6%) observed no change in rainfall amount. This observation by the majority of respondents was contrary to the actual finding from the secondary data, which was observed that during the three years prior to the study the yearly mean rainfall had increased.

Additional examination of the filled questionnaires revealed that 251 (90%) of the 300 study respondents concurred with the assertion that rainfall had become extremely unpredictable and impossible to forecast in recent years. Nevertheless, 4% of them were unsure and 6% did not agree with this assertion. These findings were consistent with the pattern observed in the inferential statistics of the secondary rainfall data provided by the Kenya Meteorological Department.

Concerning the onset of rainfall, 9.7% of small scale farmers perceived that it was coming earlier than expected. 6.3% perceived it was timely, while 84% perceived that it had been delayed in recent years. Mutunga et al. (2017) observed a similar association between smallholder farmer's perceptions and the meteorological indicators of the climatic situations in Kenya. The Kenya meteorological department had also indicated a heating trend in the temperatures between 1961 and 2019.

According to the Devolution hub (2018), Nyandarua experiences two rainfall seasons which are bimodal, with long rains in March to May reaching 1600mm and short rains in September to December reaching 700mm. Long rains have been delayed recently, extending to April or early May. This has greatly affected the planting of crops, harvesting, and output. Farmers have adjusted to this scenario by adjusting the start time for land preparation and planting dates. Howden (2012) stated that a decline in rainfall might negatively affect crop farming. Rainfall, which is crucial for 90% of Africa's agriculture, is facing significant challenges due to its unpredictable and declining nature, as highlighted by the World Health Organization (2018).

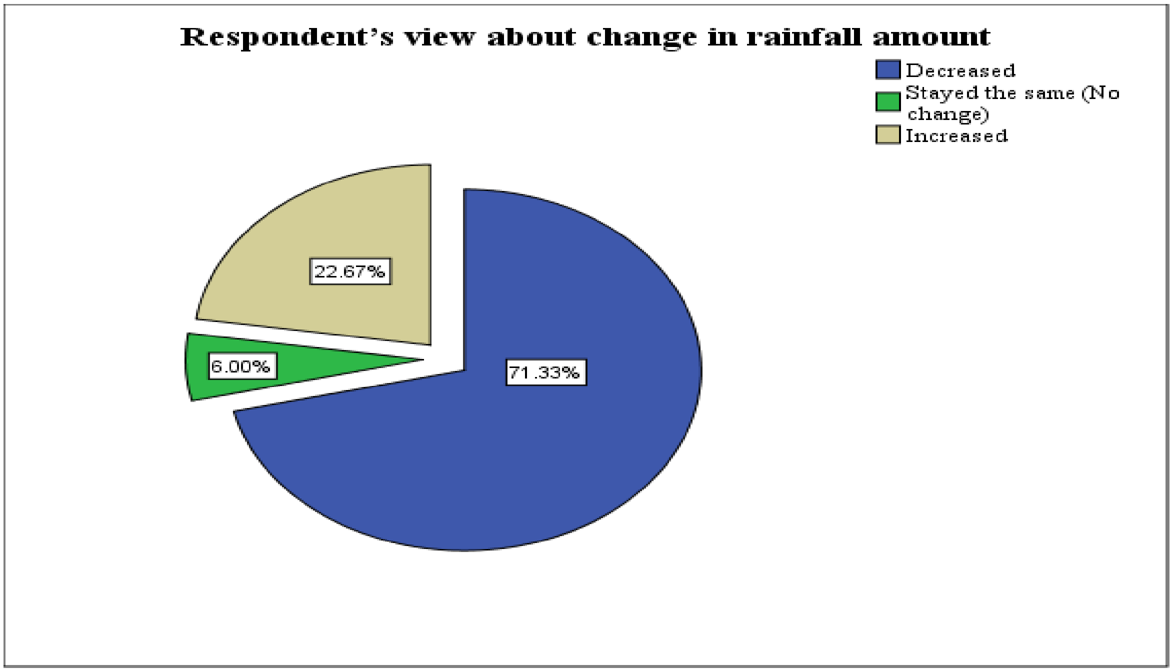



**Figure 5.12 Respondent's view about the recent change in rainfall amount**

Source: Researcher 2021

### 5.7.2 Respondent's opinion and perception of recent changes in temperature

About 83% of small scale farmers reported that they had observed some changes in temperature within the previous few years of the study. Most farmers (70%) reported that temperature had increased, 15% observed that temperature had decreased, while 14% of respondents reported that they had not perceived any temperature change. The difference in small scale farmers' perception of temperature changes could have been attributed to the inability to differentiate between minimum temperatures recorded mostly at night and maximum temperatures recorded mainly during the daytime. Results of the questionnaire analysis concerning the perception that temperature during the night had decreased in recent years were similar to the analysis of secondary data. This is because most respondents (40%) agreed that temperature during the night had decreased. Secondary data analysis revealed a significant decrease in annual lowest temperature from 11.40°C in 2001 to 8.40°C in 2009.

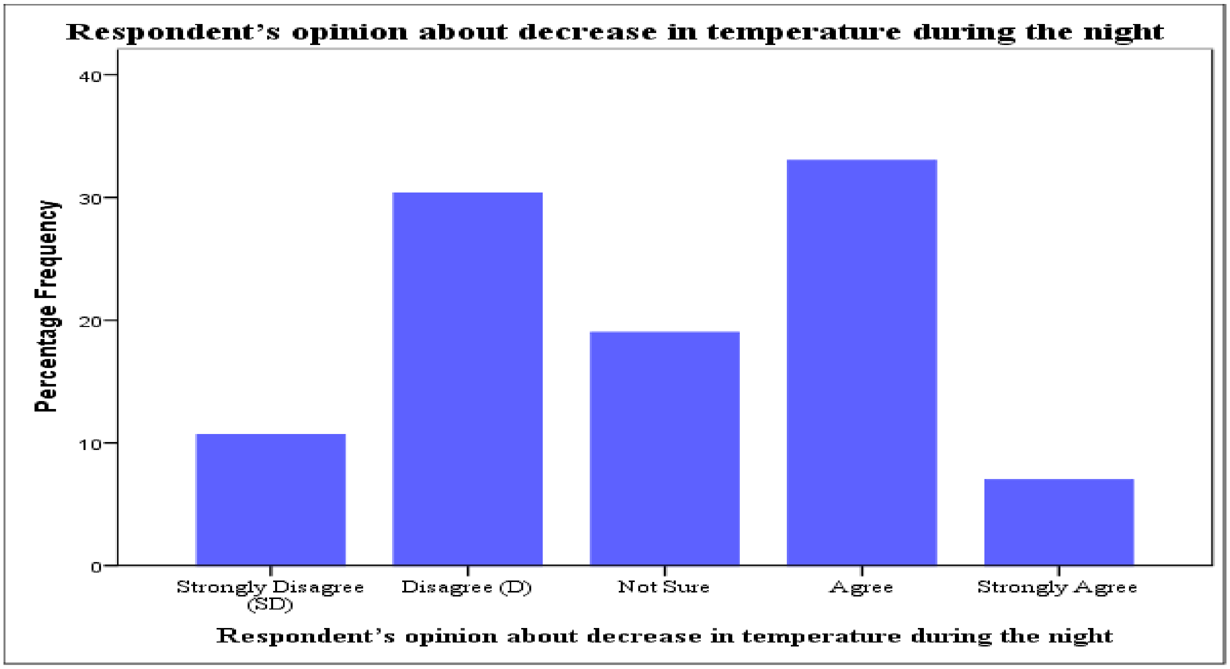



**Figure 5.13 Respondent's view about changes in temperature at night**

Source: Researcher 2021

### 5.7.3 Perception of the respondents about the changes in key crop output

Regarding variation in primary crop output, the researcher sought to analyse the opinion of small-scale farmers about the perceived changes in crop output over the recent years. Analysis from the questionnaire indicated that Irish potatoes, beans and maize were the significant crops preferred by most small scale farmers (89.7%). The County also produced various types of crops, although not many small-scale farmers were involved. These food crops comprised cabbages, kales, wheat, French beans, green peas, sorghum, millet and fruits. Regarding crop output changes, the sampled population was asked to outline how crop production or output had changed over the previous ten years. About 77.7% responded that they had not seen any change in crop output or, instead, the output remained the same. However, 12% believed that crop output had reduced, and 10.3% felt that crop output had increased. This varied response indicated that farmers could not accurately tell the change in crop output because perhaps they lacked proper record bookkeeping of the quantity of output per harvest.

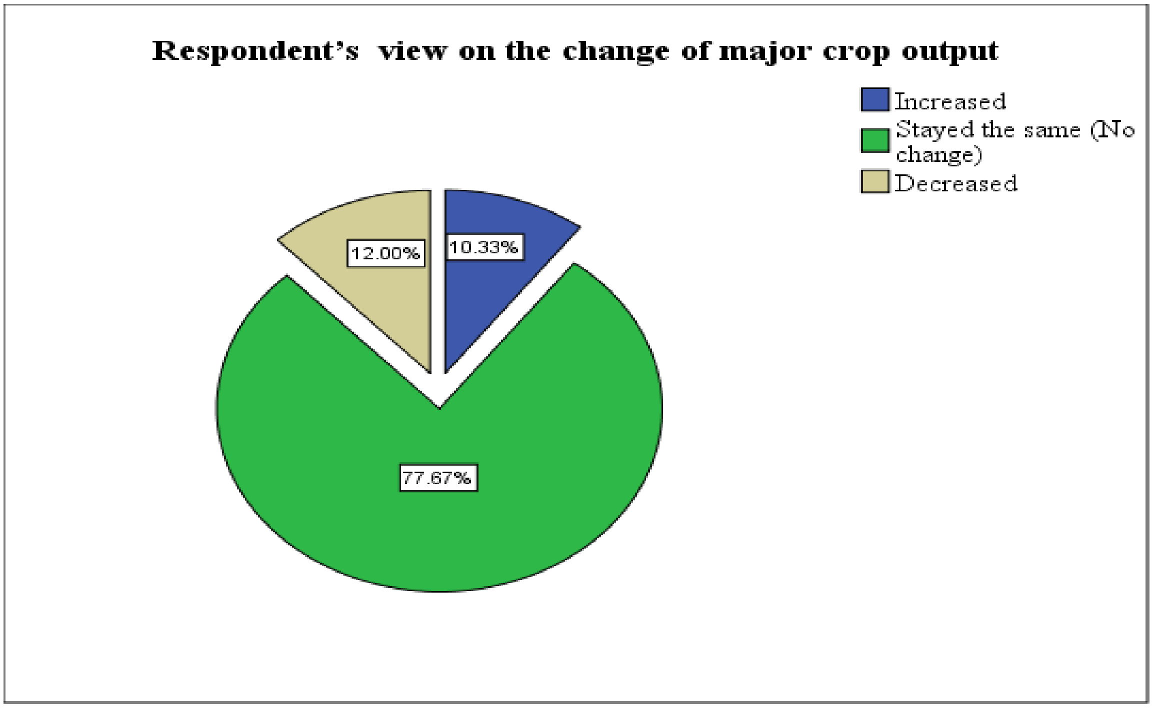



**Figure 5.14 Respondents' perception on the change in significant crop output**

Source: Researcher 2021

## 5.7.4 Respondents' opinion on causes of climate variation

With the variation of major climatic factors, the researcher sought to analyse the opinion of small- scale farming communities about the perceived causes of climate variability over the recent years. In response to the first question about what respondents thought were the causes of climate variability, the majority of household heads (59.3%) reported that climate variability was caused by deforestation, i.e. uncontrolled cutting down of trees. 27.7% thought that burning fossil fuels, e.g. cooking gas, oil and petrol, coal and plastics, significantly contributed to imminent of climate variability. A minority of the small-scale farmers (13%) did not know the causes of climate variability; therefore, it resulted from God's will.

### 5.7.5 Respondent's opinion on causes of selected crop yield variability

In connection to the second question on what the respondents would have considered as the major contributor to the changes in crop output in the area of research, the researcher confirmed that rainfall variations and temperature influenced the output of crops significantly as about 55.7% of the respondents considered climate-related factors as the primary cause of a decline in crop output. 11% of respondents considered land degradation and soil exhaustion the primary cause of the decline in crop output. In comparison, 6.7% thought that increased pests infestation and diseases significantly contributed to the decline in crop output. However, 6.7% of respondents failed to answer the question. In comparison, about 13.3% stated that other elements, like a high rate of rural-urban migration and reduction in the size and proportion of cultivatable land were the major causes of reduced selected crop yields.

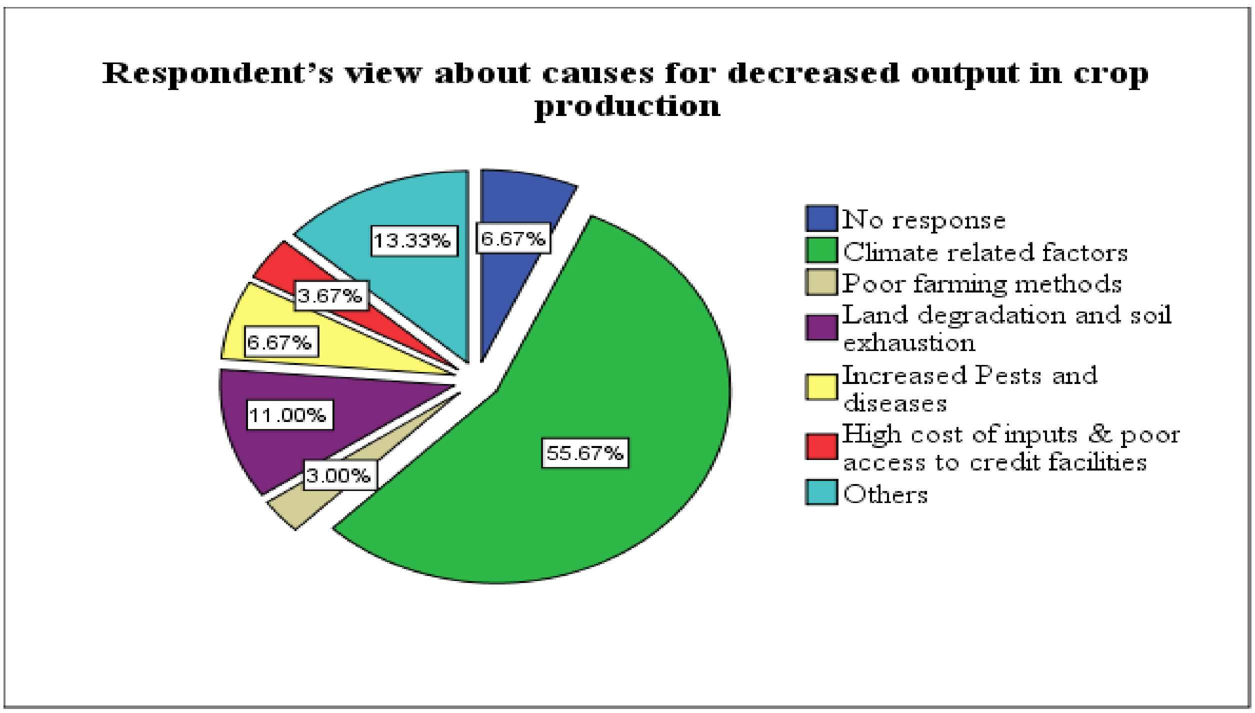



**Figure 5.15 Respondent's perception about causes for decreased output in crop output**

Source: Researcher 2021

## 5.8 Discussion of findings on climate variability effects and selected crop output

Climate variability had indeed been experienced in Nyandarua County. This variability had manifested through changes in the mean annual rainfall and the mean annual maximum and lowest temperatures for the past 21 years (1999 to 2019). The maximum temperature had generally increased from 2015 to 2019 ($20.4^0$c to $22.7^0$c). Likewise, the minimum temperature had been declining from 2010 ($8.7^0$c) to 2019 ($8.4^0$c), resulting in freezing nights affecting specific crop plants such as Irish potatoes because frostbite reduces the crop output. The secondary data about fluctuations in rainfall amount and season of temperatures collaborated with the respondent's perception of the changes in the investigated two elements or climatic variables. Nearly 83% of the small scale farmers reported that they had observed a few variations in temperature during the last few years prior to the research, and 70% of the farmers reported that the temperature had increased. About 93% of participants reported they had noticed certain changes in variation of rainfall over the last few years preceding the study. 71.3% observed that rainfall amount had decreased. Nanfuka et al (2020) observed that the Kenyan economy greatly depends on agriculture supported by rain, mostly by growing crops that are especially vulnerable to the effects and shocks of climate variability.

**Table 5.7 Nyandarua County Rainfall and Temperature Variables (1999-2019)**

| Year | Annual average, minimum temp. in $^0$c | Annual average, maximum temp. in $^0$c | Annual mean rainfall in mm |
|---|---|---|---|
| 2019 | 8.4 | 22.7 | 100.3 |
| 2018 | 8.0 | 22.1 | 87.1 |
| 2017 | 8.0 | 23.0 | 67.1 |
| 2016 | 8.1 | 22.1 | 98.0 |
| 2015 | 8.5 | 20.4 | 88.1 |
| 2014 | 7.9 | 22.1 | 74.9 |
| 2013 | 8.1 | 21.6 | 131.0 |
| 2012 | 8.3 | 21.9 | 103.5 |
| 2011 | 7.7 | 22.0 | 90.0 |
| 2010 | 8.7 | 21.4 | 109.9 |
| 2009 | 7.6 | 22.7 | 59.1 |
| 2008 | 7.6 | 21.6 | 83.4 |
| 2007 | 8.3 | 21.0 | 117.4 |
| 2006 | 7.9 | 21.6 | 89.3 |
| 2005 | 7.6 | 22.1 | 74.2 |
| 2004 | 7.5 | 21.6 | 75.6 |
| 2003 | 7.7 | 21.0 | 75.5 |
| 2002 | 11.6 | 23.9 | 80.1 |
| 2001 | 11.4 | 23.7 | 98.9 |
| 2000 | 10.6 | 24.6 | 56.0 |
| 1999 | 9.4 | 23.4 | 65.5 |

Source: Kenya Meteorological Department-Nyahururu Weather Station (2020)

Maize is Kenya's most important staple food grown in almost each of the agro ecological zones in the country. Maize is one of the main food security crops in the country and a commercial enterprise, in particular in the Rift Valley area and in certain regions of central and western Kenya (Schroeder et al., 2013). Results of the study indicate that maize and Irish potatoes are undoubtedly the most common and essential crops grown and cultivated in the County of Nyandarua. According to the study poll, 89.7% of participants said they would rather cultivate Irish potatoes, beans, and maize. This suggests that among the small-scale farmers in Nyandarua County, farming of crops was one of the primary economic activities and a substantial source of both food and revenue. The assertion by Ogola et al. (2011) that maize and Irish potatoes are staple foods and cash crops in many regions of the nation and a vital source of income for

Kenyans living in rural areas also reinforced this conclusion. The current study indicates that the Irish potato yields had increased between 2009 and 2019. The maximum were noted to be the output of 1,145,995 tonnes in 2011 and the off-peak to be the output of 84,700 tonnes in 2008. Comparing the production and output of the two selected crops of the study, it is evident that Irish potatoes contributed the highest average of 382,789.43 for the last 21 years compared to maize output with an average mean of 29,145.76 tonnes within the same period. This comparison of the mean indicates that Irish potatoes contributed the highest output and total market value in Nyandarua County. The trend of high output in Irish potatoes could have been attributed to by application of effective adaptation measures such as crop diversification, new variety seeds and proper adjustment of planting dates.

**Plate 5.1 Small scale farmers attending to a new variety of Irish potato crop**

Source: Researcher 2019

The study further indicates a significant variation in maize output in the last two decades, i.e. 1999 to 2019. Indeed, there was a sharp drop in maize output recorded between 2013 and 2014. The World Bank (2010) asserted that declining maize yield should be treated with caution. This is because the population density has been increasing, leading to a rise in the demand for food. The size of cultivatable land has also been decreasing, resulting in decreased maize output. The study indicated that there had been periodical peaks and off peaks of maize and Irish potato output for the last 21 years. The peaks may have been caused by favourable weather and climatic conditions that are essential for crop growth, the push for hybrid seed and accompanying technology adaption, and, to some extent, a rise in the area under cultivation. Similarly, factors like unfavourable weather patterns, land shrinkage, a rise in crops illnesses and pests, degraded land and decreasing soil fertility, high input costs, and significant post-harvests losses could have been responsible for the off-peak years that were observed (Ingram et al., 2011).

**Table 5.8 Nyandarua County crop output variables (1999-2019)**

| **Crop** | **Irish Potatoes** | | **Maize** | |
|---|---|---|---|---|
| Year | Output In Tonnes | Acreage In Hectares | Output In Tonnes | Acreage In Hectares |
| 2019 | 413,160 | 37,860 | 37,184 | 16,906 |
| 2018 | 305,250 | 37,000 | 34,289 | 17,885 |
| 2017 | 555,000 | 37,000 | 21,870 | 16,200 |
| 2016 | 451,290 | 33,035 | 27,594 | 16,300 |
| 2015 | 598,500 | 38,500 | 26,576 | 17,837 |
| 2014 | 551,657 | 36,400 | 14,017 | 17,104 |
| 2013 | 473,343 | 36,446 | 53,575 | 19,842 |
| 2012 | 230,825 | 36,365 | 51,300 | 19,000 |
| 2011 | 1,143,955 | 38,133 | 54,951 | 20,352 |
| 2010 | 910,300 | 36,412 | 40,500 | 18,000 |
| 2009 | 402,000 | 20,100 | 24,098 | 17,850 |
| 2008 | 84,700 | 11,000 | 14,367 | 19,440 |
| 2007 | 446,775 | 38,850 | 23,500 | 19,080 |
| 2006 | 105,840 | 37,800 | 37,538 | 20,020 |
| 2005 | 309,205 | 23,735 | 22,330 | 11,165 |
| 2004 | 93,320 | 15,020 | 25,290 | 16,800 |
| 2003 | 230,080 | 14,380 | 24,735 | 14,550 |
| 2002 | 210,240 | 12,140 | 24,917 | 14,950 |
| 2001 | 198,720 | 12,420 | 30,483 | 15,500 |
| 2000 | 124,500 | 12,450 | 10,343 | 14,365 |
| 1999 | 199,878 | 14,377 | 12,604 | 14,004 |

Source: Nyandarua County Government (2020)

Some relationships were noted between rainfall amount and maize output. In the year 2000, rainfall amount was found to be the lowest at an annual average of 56 mm. Likewise; the same year maize recorded the lowest output (10,343 tonnes). In 2012 and 2013, rainfall was highest at an annual average of 103mm and 131mm, respectively. Likewise, maize recorded the highest output (51,300 and 53,575 tonnes). Correlation analysis between mean annual rainfall and the selected crop output revealed an exciting scenario. The mean annual rainfall correlation values of $r$ =0.687 and $r$ =0.296 with maize and Irish potatoes suggested that an increase in rainfall increased selected crop output. The low correlation coefficient value of Irish potatoes (r=0.296) regarding rainfall could have been that perhaps Irish potatoes take less time to grow and mature, i.e. three months, unlike maize which is an annual food crop in Nyandarua County. This could probably mean that rainfall variation does not significantly influence the Irish potatoes' output as much as maize output.

On the contrary, the negative correlation of annual mean temperature indicates that an increase in minimum and maximum temperature decreased both crops' output. The results further indicated that the trend in rainfall amount had a more significant effect on crop yields ($r$ =0.687) than maximum and minimum temperature. Crop output and agricultural production are greatly influenced by rainfall amount, reliability and distribution that eventually controls the duration of the growth season and thus food crop yields and output (FAO, 2012). The findings make it clear that adequate rainfall amount and distribution are crucial for sound crop output. However, excessive rainfall may destroy crops, especially during the flowering and development stages. Flooding as a result of excessive rainfall may result in reduced crop yields. A good example is the 1997 El-Nino rainfall that significantly destroyed many crops and reduced crop yield and loss of harvests.

Maize crop damaged by hailstones    Cabbage crop damaged by hailstones

**Plate 5.2 Negative effect of torrential rainfall on crops in the year 2019**

Source: Researcher 2019

The trend line and scatter graph of rainfall and temperature indicated that variations of these climatic variables were conspicuous. In addition, these graphs and trend lines indicated that the variables were very unpredictable, affecting farmers' preparedness for farming. Results of temperature variability may be associated with a study by Jaramillo et al. (2009), which showed that high temperatures might be associated with some pests and diseases that may attack crops leading to reduced crop yields. A crop's ability to grow, flower, mature, and provide high yields depends on photosynthesis, which depends on the ideal temperature (Gornall et al., 2010). According to Dell et al. (2008), a one-degree Celsius yearly temperature increase has a detrimental impact on a wide range of staple crops that are farmed by rural farmers in Africa, especially in Kenya. Overall, these results were consistent with the questionnaire responses given to the participants, which showed that roughly 55.7% of the participants believed that issues connected to climate change were the main reason behind the decrease in crop yield. Similar findings were reported by Maddison (2006), who found that many small-scale farmers in the eleven African nations he studied thought that the temperature had risen while the intensity of the rainfall had decreased.

## 5.9 Conclusion

Based on the initial results, the two climatic factors considered in this study, namely mean annual rainfall and mean annual temperature, were found to have influenced the output of maize crops within 21 years (1999-2019). In this case, the null hypothesis that rainfall and temperature variability had not significantly impacted crop farming (maize output) in Nyandarua County was rejected. However, the same climatic factors considered in this study were found not to have influenced the outcome of Irish potato crop yields within the same period. This means that there could have been no enough evidence of rejecting the negative hypothesis. Therefore, the hypothesis that rainfall and temperature variability did not significantly impacted crop farming (Irish potatoes output) in Nyandarua County failed to be rejected.

It is hence forth evident from the results discussion that rainfall, particularly for maize in Nyandarua County, is a key predictor of crop yield. Temperature variability, however, did not yield much significant relationship with both crops' output. It is also noted that Irish potatoes contributed the most considerable output in Nyandarua County between the years 1999 and 2019. Based on the fact that climate variability contributed to only a very small percentage of variations in Irish potatoes, then it goes without saying that other factors must have contributed a role in the variability of Irish potatoes observed in this study. This scenario creates a gap for further studies.

In general, this chapter's findings show that at least 50% of the variation in maize and Irish potato output could not be accounted for by the variations of the two climatic factors considered in this study. This finding opens a new frontier of knowledge that the selected climatic factors alone cannot guarantee sustainable crop output. In this case, other agronomic factors such as morphological properties of soils, proper application of fertilizers, disease and pest control, change in the proportions of cultivable lands, management of post-harvests losses, etc., play greater role in determining the output of major crops in Kenya. These factors must essentially be moderated by proper adaptation strategies, which may have been influenced by a variety of demographic and socio-economic factors which may either form opportunities or limitations for effective adaptation measures. These reasons necessitate the need to critically document, analyse and evaluate the effectiveness of the key adaptation strategies applied by small scale farmers to cushion themselves against the unprecedented effect of climate variability. These knowledge gaps have been further studied in the subsequent chapters of this study.

# CHAPTER SIX

## SOCIO-ECONOMIC FACTORS AND CROP FARMING ADAPTATIONS TO CLIMATE VARIABILITY

### 6.1 Introduction

This chapter assessed the relationships and links between the socio-economic variables and the strategies of adaptations employed by small-holder farmers as mitigation measures against the impacts of climatic variations of key elements on crop farming. The content in this chapter is associated with the second objective and tests the second hypothesis of the research study. The chapter begins by describing the respondents' demographic and socio-economic characteristics, followed by a description of the key adaptations and mitigation strategies adopted by small-scale farmers in Nyandarua County. The chapter presents multinomial regression results that illustrate the association between the important adaptation techniques and the chosen demographic and socioeconomic parameters of the respondents in order to evaluate the socio-economic determinants of crop farming adaptation and mitigation measures. This chapter tests the second hypothesis, which holds that the adaptation strategies used by small-scale farmers are not significantly influenced by demographic and socioeconomic factors such as age, gender, size, land ownership, income level, and education. The findings are then discussed.

### 6.2 Demographic and Socio economic information of the respondents

Assessment of age, gender, size of cultivatable land, ownership of land, income levels, and levels of education of the respondents (i.e. small-scale farmer) was necessary because it brings out knowledge and understanding of how these factors may have affected and influenced the crop farming adaptations to climate variability and crop output among the small-scale farmers (Helena et al., 2014). In this study, the researcher sought to establish socio economic underlying conditions and characteristics about the research study groups and their relationship with crop farming adaptation strategies. This primary data was obtained from the questionnaires administered to 300 small scale farmers in Nyandarua County. The variables assessed in this section were marital status, age, household size, gender and income source, level of income, level of education, size, and ownership of land under cultivation.

### 6.2.1 Age of the respondents

The description of this variable in figure 6.1 revealed that most respondents were aged above 36 years (68.57%). The age cohort by the majority of respondents (25.42%) was 46-55 years. The age bracket of 36-45 years followed with 23.75%. The lowest response rate was obtained by 9.03% of respondents under the age of 25, while one respondent (0.3%) did not provide his age. The study's findings suggest that the younger generation had not fully embraced crop farming in Nyandarua. This is because most of them were still in school; others have migrated to urban centres to search for employment, while others could have had a negative perception regarding farming as a means of subsistence and livelihood. Regarding how climate variations negatively affect crop farming, the young population was not directly affected. This is because most of the young population, less than 25 years, do not own land and did not engage in active farming practices. Nevertheless, it was evident that the older population in Nyandarua was engaged in small scale farming, which could mean that they had extensive skills and experiences in agriculture. They were likely to adapt and adjust to variations of climate or its variability more efficiently and effectively than the young population.

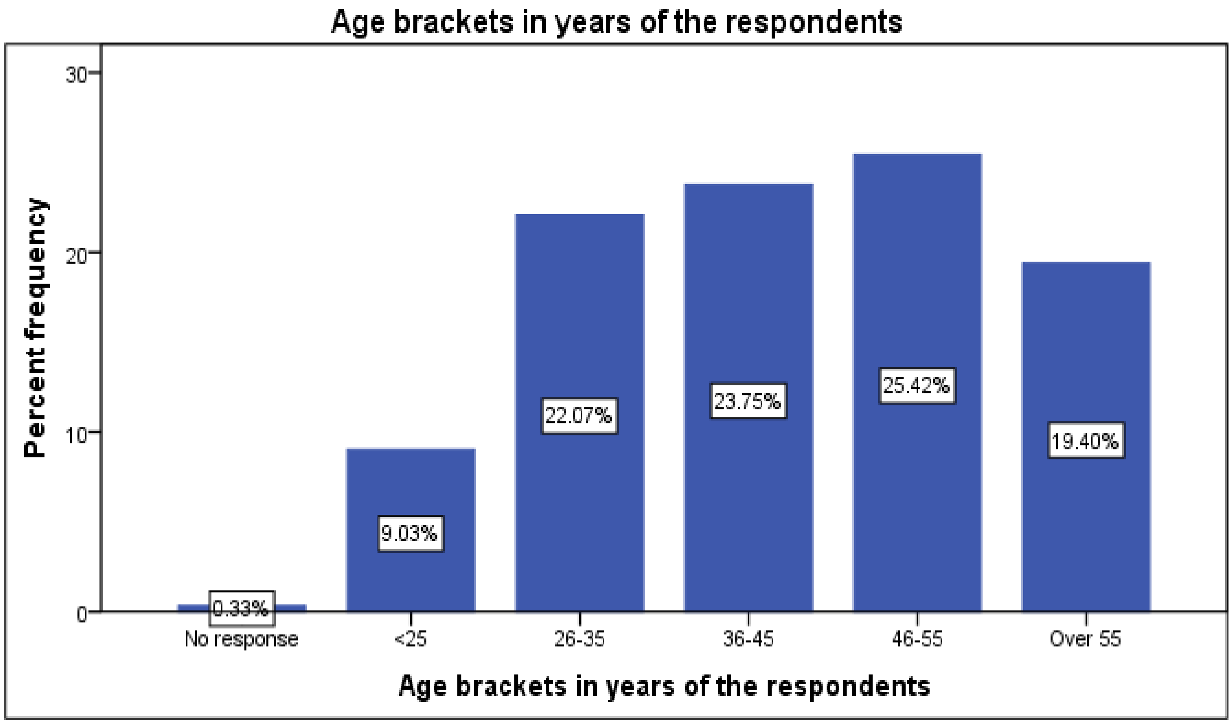



**Figure 6.1: Age brackets of the respondents**

Source: Researcher 2021

### 6.2.2 Gender of the respondent

Of the 300 questionnaires administered, 63.67% of respondents were male, and 36.33% were female. Focusing on the head of the household as the responder may have contributed to the high proportion of male respondents. However, none of the respondents failed to report the gender or reported as being trans-gender. This demographic characteristic was considered vital because it was likely to influence the uptake of specific adaptation strategies due to gender differences in the role played within the household, acquisition and ownership of assets and decision making within the family. A study in semi-arid areas by Campbell et al., 2002 on on the standards and types of livelihoods affecting households showed that both female and male genders were involved in small scale farming activities. But still, they responded differently to critical climatic variables.

### 6.2.3 Marital status of the respondents

Regarding this variable, past empirical studies indicate that female divorcees and windows are disadvantaged in the application of specific crop farming adaptation strategies such as water management and irrigation (Jin et al., 2015). This is because of their weak income status and poor adaptive capacity (Jinhong et al., 2016). The research found that majority of the respondents household heads (74.3%) were married, while only (25%) were single. This variable description meant that many of the small-scale farmers in Nyandarua had settled for quite some time in the region with steady families and perhaps an indicator of increased livelihoods diversifications through certain non-farm income-earning activities. On the other hand, married couples were likely to have more adaptive capacity than non-married respondents because of heavy family responsibilities.

**Table 6.1: Respondent's marital status**

| Marital status | Incidence | Percentage | Aggregate % |
|---|---|---|---|
| Married | 223 | 74.30 | 99.33 |
| Single | 75 | 25.00 | 25.00 |
| No response | 2 | 0.70 | 100.00 |
| Total | 300 | 100.00 | |

Source: Researcher 2021

### 6.2.4 Household size

Regarding the family size, the 2009 census report placed Nyandarua County at an average of five members per household. In this study, 45% of the respondents reported having 5-8 members, and only 3.7% of the respondents reported having more than 13 members. The size of households has a current and future implication on the size of cultivatable land due to land fragmentation attributed to the increase in population. The population growth projection of 2% indicates that the land size will shrink significantly, reducing the effectiveness of specific adaptation strategies applied like crop diversification and rotation, especially in crop farming.

**Table 6.2: The size of the household for the respondent**

| Household size | Frequency | % | Cumulative Percentage |
|---|---|---|---|
| 1-4 | 119 | 39.70 | 39.70 |
| 5-8 | 135 | 45.00 | 84.70 |
| 9-12 | 35 | 11.70 | 96.30 |
| 13> | 11 | 3.70 | 100.00 |
| Over all Total | 300 | 100.00 | |

Source: Researcher 2021

### 6.2.5 Sources and levels of income

The study results presented that crops farming and cultivation was the primary source of livelihood and income revenues among many small holder farmers in the region of Nyandarua County (53%). The casual labour was reported as a minor source of income (0.67%). However, most respondents reported to have had various sources of income, an idea that revealed they had engaged in some forms of income diversification. This finding could be attributed to less income earning obtained from farming. Formal employment was found low as most farmers reported this source were teachers. It indicated that most people in formal employment reside in towns with little urban crop farming. Related to the source of income, the researcher also intended to establish the revenue per household. The reason is that some adaptation strategies are costly and require high finances, which is not available. 38% of the respondents' monthly income was less than Ksh. 10,000. The low-income and livelihood level had been hypothesized and thought to affect the application of certain adaptation techniques and strategies. Low income levels and sources of livelihood were therefore expected to be among the major obstacles and constraints that would prevent appropriate and effective adjustments to climate variability.

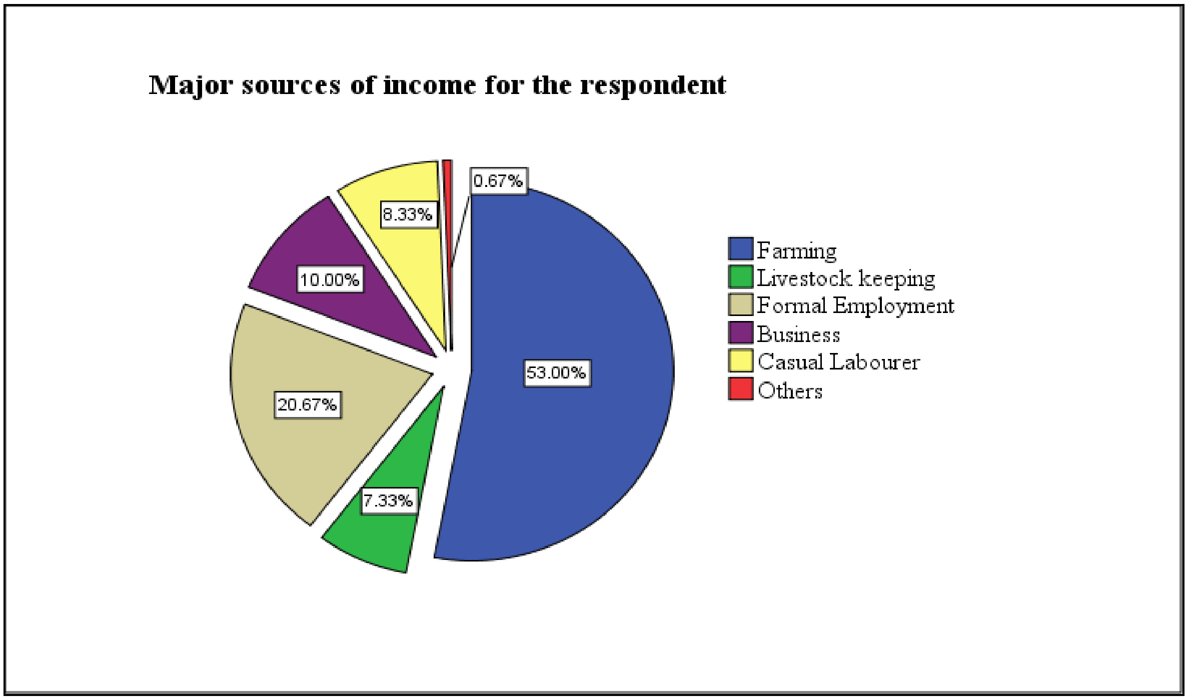



**Figure 6.2: Sources of income**

Source: Researcher 2021

**Table 6.3: Distribution of levels of incomes and earnings among the respondents**

| Income per month in Ksh. | Frequency | % | Cumulative percentage |
|---|---|---|---|
| <10,000 | 114 | 38.00 | 38.00 |
| 10,001-20,000 | 95 | 31.70 | 69.70 |
| 20,001-30,000 | 40 | 13.30 | 83.00 |
| 30,001-50,000 | 44 | 14.70 | 97.70 |
| >50,0001 | 7 | 2.30 | 100.00 |
| Total | 300 | 100.00 | |

Source: Researcher 2021

## 6.2.6 Level of education;

The study included the level of education as a variable which was evaluated to assess its impact as a determinant to climate variability adaptations. The education level in this study was grouped into five classes: no education, Primary, Secondary, College, and University levels. The findings acknowledged that there were a large number of small-scale farmers, who could attest to having more education, which the study anticipated would possibly positively contribute to effective adaptations. Education attainment at the secondary level was 43.33%, college level at 20%, and university level at 11.3%. High primary school dropout rates was a significant contributor to low levels of education (25%), which was mainly the case for girls who dropped out because of early marriages and pregnancies (Glennerster et al., 2011). The level of education was suggested to have had a direct significance on small-scale farmers' perceptions of the climate variability, its impact, and coping strategies. It was envisaged that the respondent's higher levels of education contributed to increased knowledge of the variability and adaptation of the climate. In this case, attaining higher education was likely to reduce the effects of climate changes and variations.

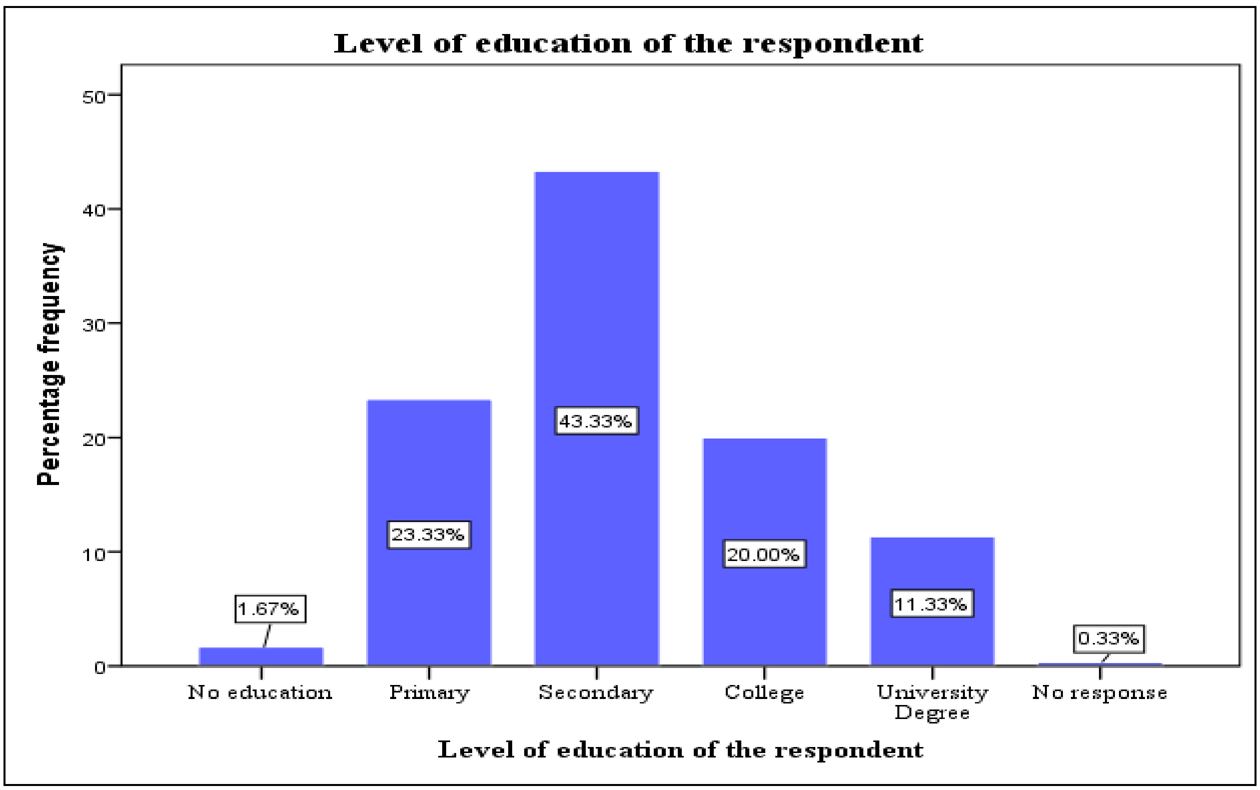



**Figure 6.3: Levels of education**

Source: Researcher 2021

### 6.2.7 Size and ownership of land under cultivation

This variable is one of the critical determinants of effective crops adaptability by small-scale farmers to variations in the climate. The explanation is that the type of adaptation tactics used depends heavily on the land tenure. Likewise, the amount of land affects the type and magnitude of technology used. With the current high population growth, land under cultivation is becoming smaller and smaller. This scenario results from a high rate of land divided into smaller plots for inheritance or sale. This land fragmentation process had contributed to low crop yields and output across several regions of the nation (Wambua & Kithiia, 2014). The study results portrayed a situation where many small-scale farmers privately owned land under cultivation (67.7%). However, of great interest to note is that land under cultivation was small, ranging from 2-5 acres (62%). This situation implied that these small pieces of land could not be put into practical commercial farming. As a result, it was likely to affect future crop output and food security. According to Mutisya D. (2000), small farms with 2.5 acres can enhance crop output through intensive cultivation using manure, fertilizers, soil conservation measures, and modern seed varieties.

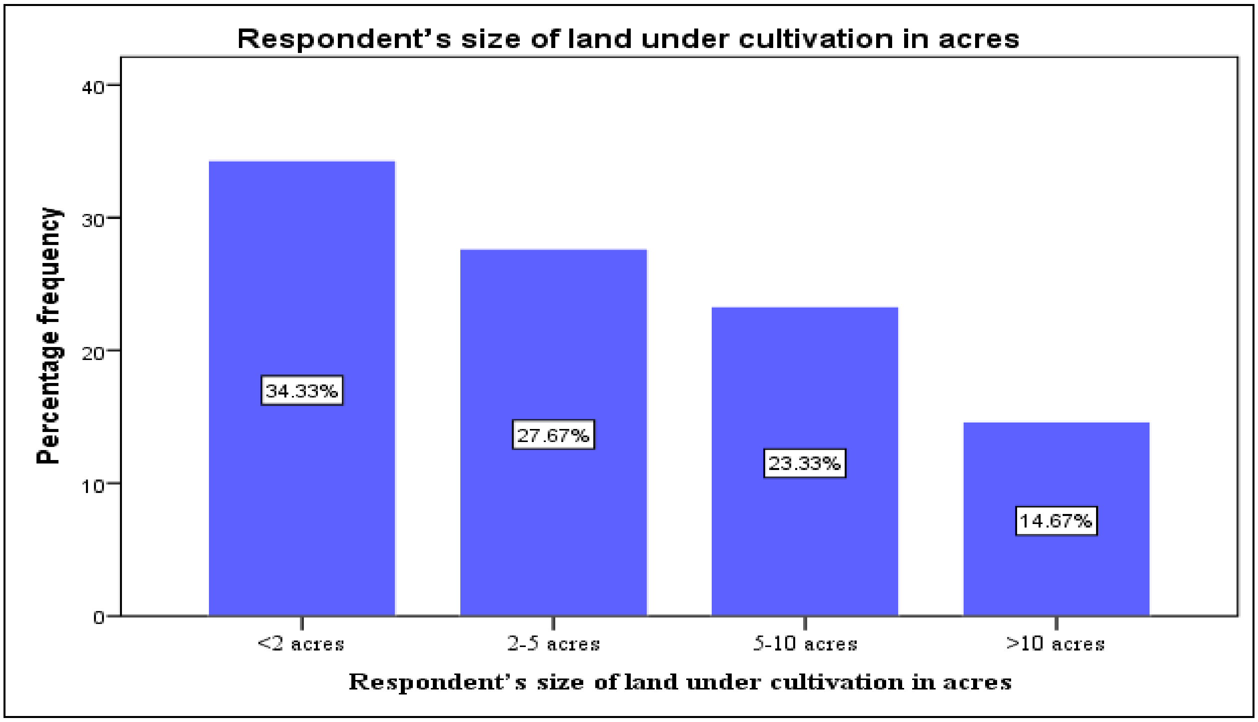



**Figure 6.4: Size of land under cultivation**

Source: Researcher 2021

**Table 6.4: Land tenure/ownership of land under cultivation**

| Land tenure/ownership | Frequency | Percentage | Cumulative % |
|---|---|---|---|
| Privately Owned | 203 | 67.7 | 67.7 |
| Communal ownership | 6 | 2.0 | 69.7 |
| Rented | 57 | 19.0 | 88.7 |
| Leased | 5 | 1.7 | 90.3 |
| Others | 29 | 9.7 | 100.0 |
| Total | 300 | 100.00 | |

Source: Researcher 2021

## 6.3 The small-scale farmers' adaptation responses

From the respondent's findings, about 13.8% reported they had changed the planting dates causing variation in planting and harvesting periods. This adaptation strategy was caused by either delay or earlier onset of rainfall. Sorghum, pumpkins, and millet were grown by about

20.3 percent of the respondents because they were considered to be more resistant to climate changes and variabilities. Most small scale farmers (21.2 percent) used crop diversification, which involved planting many crops on the same piece of land. Around 12.4 percent of small scale farmers had chosen to use crop irrigation methods to boost crop yields and revenues, while 4.9 percent of respondents saw looking for off-farm work as an adaptation strategy. The lowest adaption ratings were 5.6 percent and 2.1 percent for greenhouse farming technology and crop insurance, respectively. Other adaptation strategies captured by the questionnaire administration were employed by 15.2 percent of respondents. These strategies included; manure application for soil conservation practices, changing livestock farming, use of fertilizers, increasing the size of cultivatable land areas, mixed crop farming, and agroforestry.

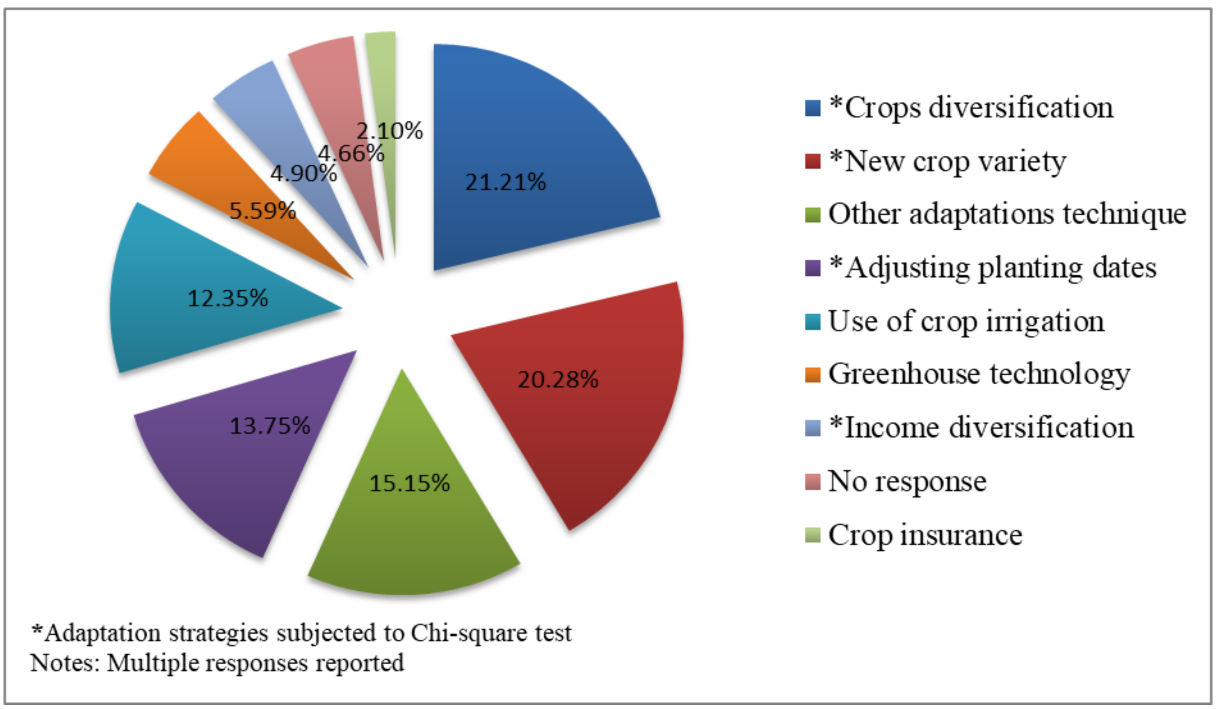



**Figure 6.5: Types of coping/adaptation strategies applied by the respondents**

Source: Researcher 2021

## 6.4 Socio-economic factors and key adaptation strategies for crop farming

The study's second objective was to assess the influence and relationship of socio economic factors and adaptation strategies on crop farming. The study used the multinomial logistic regression statistical analysis to determine and predict the significant association between the independent socio-economic factors and the dependent adaptation strategies under investigation. The adaptation strategies for this statistical test included crop diversification, planting new resistant/fast-maturing crop varieties, adjusting sowing dates, and income or revenue diversification. The study assumed farmers could only adopt one strategy at a time. In this case, adaptation to strategy 1 was coded as follows; adopters =1, non-adopters =0.

In order to establish and assess the relationship between the socio-economic factors of respondents and crop farming adaptation strategies, the study used the Multinomial logistic regression model (MLR) to analyze the determinants impacting farming households' decision of adaptation techniques to climate variability. In contrast, the study used descriptive statistics to analyze the associated effects of household socio economic factors on the adaptation measures and strategies. Descriptive statistics in Table 6.5 showed a close variance of statistics between socio-economic factors and the adaptation strategies applied by the small scale farmers. The standard deviation of 0.2 to 1.2 in both descriptive statistical tables indicates that the data was well distributed within the mean. The distribution of descriptive statistics confirmed that the data collected was significant to test the null hypothesis and make valid conclusions.

**Table 6.5: Variability of socio-economic factors affecting crop adaptations to climate variability**

**Descriptive Statistics 1**

| Independent Variables | N | Mean | Std. Deviation | Variance |
|---|---|---|---|---|
| Age brackets in yrs. of the respondent | 299 | 3.2308 | 1.26262 | 1.594 |
| Gender of the respondent | 300 | 1.3633 | .48176 | .232 |
| Size of land under cultivation in acres | 300 | 2.1833 | 1.06466 | 1.134 |
| Total monthly income in Ksh. for the respondent | 300 | 2.1167 | 1.14049 | 1.301 |
| Level of education of the respondent | 300 | 2.1633 | .96597 | .933 |
| Total Valid N (list wise) | 299 | | | |

**Descriptive Statistics 2**

| Dependent Variables | N | Mean | Std. Deviation | Variance |
|---|---|---|---|---|
| Crops diversification | 300 | 1.7100 | .45452 | .207 |
| New maturing crop variety | 300 | 1.7100 | .45452 | .207 |
| Adjusting planting dates | 300 | 1.8133 | .39029 | .152 |
| Income diversification | 300 | 1.9300 | .25557 | .065 |
| Total Valid N (list wise) | 300 | | | |

Source: Researcher 2021

## 6.5 Crop diversification as a strategy to cope with climate variability

There were multiple determinants that influenced farmers' decision of crop diversification in Nyandarua County as a long-term climate variability adaptation strategy. Respondents with at least a college level of education (35.3%) reported adopting this crop diversification adaptation strategy method. This outcome implied that higher education levels positively determined this adaptation strategy's effectiveness. Based on this specific adaptation strategy analysis, women were found to have applied this adaptation strategy more efficiently than men. It was concluded that if women are empowered through access to quality education, income security and stable land tenure, they can be greater adapters to diversification of crops as an adjustment strategy to the effects climate variations. Perhaps this is because women are much more concerned about the quality and quantity of food on the table and the well-being of children.

**Table 6.6 Level of education and Crops diversification - Cross tabulations**

| % Within the Levels of education of the respondent | Crops diversification | | Total |
|---|---|---|---|
| | Yes | No | |
| No education | 0.0% | 100% | 100% |
| Primary | 27.1% | 72.9% | 100% |
| Secondary | 29.5% | 70.5% | 100% |
| College | 35.3% | 64.7% | 100% |
| University Degree | 29.5% | 70.5% | 100% |
| Total | 29.0% | 71.0% | 100% |

Source: Researcher 2021

Multinomial regression analysis of determinants impacting small scale farmers' adoption to crop diversification was accurate in predicting 54.7% of the adopters and non-adopters of crop diversification with a significance level of $p<0.01$. The likelihood ratio tests for this model indicate that X variables added to the model significantly improved the model compared to the intercept alone. Pseudo $R^2$ indicates that a 16.7% proportion of variance between the crop diversification adopters and non-adopters was explained by the model. The goodness of fit for this model was poor because the Pearson chi-square statistic values were large. However, the P-significance value of 0.000 specifies that this related model was actually statistically significant and, therefore, the statistical model fitted the collected data well.

## Table 6.7: Factors influencing small scale farmers' adaptation to crop diversification in Nyandarua County

| **The dependent variable is adoption crop diversification (Yes-1)** | | | | | | 95% Confidence Interval for Exp(β) | |
|---|---|---|---|---|---|---|---|
| **Independent variables** | B | Std. Error | Wald | Sig. | Exp(β) | Lower Bound | Upper Bound |
| Intercept | -1.556 | .956 | 2.652 | .103 | | | |
| Age of the respondent | -.012 | .114 | .012 | .914 | .988 | .789 | 1.236 |
| Gender of the respondent | .155 | .274 | .319 | .572 | 1.167 | .682 | 1.997 |
| Size of the household | -.103 | .174 | .351 | .554 | .902 | .642 | 1.268 |
| Level of education | .108 | .152 | .502 | .479 | 1.114 | .826 | 1.501 |
| Monthly income in Ksh. | .067 | .122 | .302 | .583 | 1.069 | .842 | 1.358 |
| Ownership of land | -.185 | .111 | 2.772 | .096 | .831 | .669 | 1.033 |
| Size of land under cultivation | .103 | .127 | .650 | .420 | 1.108 | .863 | 1.422 |
| Type of farming system | .153 | .066 | 5.346 | .021 | 1.166 | 1.024 | 1.328 |
| Changes in crop yields | -.118 | .275 | .184 | .668 | .889 | .519 | 1.523 |
| Effectiveness of the adaptation strategy | .378* | .142 | 7.110 | .008 | 1.460 | 1.105 | 1.927 |
| Model diagnosis | | | | | | | |
| Count of the observations | 300 | | | | | | |
| Log likelihood | 352.29 | | | | | | |
| Wald (LR) Chi square | 54.7 | | | | | | |
| Model significance level | P=0.003 | | | | | | |
| Pseudo $R^2$ | 0.167 | | | | | | |

The reference category is non-adoption of crop diversification (No-0)

*Significant at 5% probability level

Source: Researcher 2021

The respondent's age negatively influenced small scale farmer’s decision to use this adaptation technique to curb themselves against the effects of climate variability on cropping activities (β=-0.012). This finding assumes that farmers who were older tended to adjust to this adaptation much more than the young farmers in terms of age. On the other hand, the head of the household's gender designation absolutely influenced the acceptance of this adaptation strategy (β=0.155). These results meant that households dominated by females were likely to adapt much faster to crop diversification than male-led households. The logic implied is that perhaps women are much more concerned about the crop output as they bear the most significant responsibility of ensuring that children access enough food daily. Income level significantly and positively influenced the adaptation to crop diversification as an adaptation option. ($\beta$=0.067). As the monthly income increased by Ksh. 1,000, there was a consequential increase of the possibility of using different crop types of varieties by less than 0.001. The knowledge generated is that there were more financial costs associated with crop diversification compared to changing plating schedules and changing crop varieties. The impact of higher financial freedom in using crop diversification was that the farmers were less likely to be affected by extreme climatic changes because they could adapt quickly, and they benefitted from information accessibility and long-term planning strategies. These results concurred with the findings of Deressa et al. (2010). They found that the elderly farmers were more experienced in applying these adaptation strategies because they were significantly exposed to previous and present climatic conditions.

## 6.6 Adaptation to climate variability through planting of new crop variety

The model was significant at p=0.000 with Wald of $X^2$=62.23, indicating a powerful explanatory impact, as shown in table 6.8. In addition, the MLR analysis of determinants impacting small scale farmers' adaptation of new varieties of crops tolerant to climate variability in Nyandarua County, such as sorghum, millet, fast-maturing maize variety, hybrid maize variety, drought resistant Irish potatoes variety and others, demonstrated that the model made accurate predictions (59.8%) of adopters and non-adopters to drought-resistant strategies at a significance of $p<0.01$ as depicted in Table 6.8. However, all the variables apart from the adaptation strategy's effectiveness were insignificant in explaining the adoption of this adaptation strategy. The efficiency of this adaptation method in influencing agricultural yield was consistent with research that proposed planting more resilient variety of crop types was one of the common adaptation tactics to lessen climate variability's effects (IPCC, 2007). This conclusion was also backed up by a research conducted in Vihiga County, which found that average yields for drought resistant duo-purpose potatoes' types, combined with better-quality breeds and nutritious animal feeds, would completely counteract the effects of climate unpredictability (Tachie-Obeng et al., 2012). Kelvin et al., (2016) discovered that introducing heat-tolerant cultivars to Ghana would significantly boost maize yields.

## Table 6.8: Determinants impacting small scale farmers' adaptation to new crop variety in Nyandarua County

| **The dependent variable is the adoption of a new crop variety (Yes-1)** | | | | | | 95% Confidence Interval for Exp(β) | |
|---|---|---|---|---|---|---|---|
| **Independent variables** | B | Std. Error | Wald | Sig. | Exp(β) | Lower Bound | Upper Bound |
| Intercept | -2.212 | .973 | 5.165 | .023 | | | |
| Male or female respondent | .038 | .281 | .019 | .892 | 1.039 | .599 | 1.801 |
| Respondent's Age | .003 | .116 | .001 | .978 | 1.003 | .799 | 1.260 |
| Size of the household | -.088 | .173 | .261 | .609 | .915 | .652 | 1.285 |
| Monthly income in Ksh. | .258 | .122 | 4.433 | .035 | 1.294 | 1.018 | 1.645 |
| Level of education | .165 | .153 | 1.165 | .280 | 1.180 | .874 | 1.593 |
| Ownership of land under cultivation | -.028 | .106 | .070 | .791 | .972 | .791 | 1.196 |
| Type of farming system | .098 | .067 | 2.158 | .142 | 1.103 | .968 | 1.257 |
| Size of cultivated land | -.284 | .128 | 4.973 | .026 | 1.329 | 1.035 | 1.706 |
| Changes in crop yields | -.273 | .273 | 1.004 | .316 | .761 | .446 | 1.299 |
| Effectiveness of the adaptation strategy | .506* | .151 | 11.200 | .001 | 1.659 | 1.233 | 2.232 |
| Model diagnosis | | | | | | | |
| Quantity of observations | 300 | | | | | | |
| Log likelihood | 353.67 | | | | | | |
| Wald (LR) Chi square | 62.23 | | | | | | |
| Model significance level | P=0.000 | | | | | | |
| Pseudo $R^2$ | 0.598 | | | | | | |

*Significant at 5% probability level

Source: Researcher 2021

The respondent's age positively influenced the adaptation strategy of planting a new crop variety. This is because the associated alpha (β =0.003) was positive. Household heads who were old were found to have used this adaptation strategy more than the young respondents. Likewise, the size and proportion of land cultivated negatively influenced the adoption of this adaptation strategy (β =-.284). This implied that farmers with small land sizes under cultivation adapted to planting new crop varieties, unlike those farmers with huge tracts of land. The level of education positively influenced the farmers to change the crop variety. This indicates that higher education levels enabled the small scale farmers to practice changing crop variety compared to small scale farmers with low levels of education. Educated farmers perhaps had acquired awareness and skills through seminars and workshops where they could have been trained on the better crop varieties to adapt to the shifting patterns of the climate. The perception that this adaptation strategy was effective significantly contributed to its implementation by the farming communities. This is because farmers perceived that climate variability was very extreme and required crop variety change. The current results corresponded with the findings of Deressa et al. (2012). They found that the elderly farmers were more experienced in applying these adaptation strategies because they were extensively exposed to historical and present climatic conditions. In connection to the Gender of the respondents, the current study results concurred with Bryan et al. (2013) study, whose findings acknowledged that traditions and gender norms hindered the adaptation of adopting a new crop variety by women, mainly because they had limited responsibilities in households' decision-making (β =0.006). A study by Limo (2013) found that it was more likely for male tea farmers to use crop farming adaptation strategies than women. This conclusion was not found to be true in this study.

Hassan and Nhemachena (2008) found that the farm's size under cultivation negatively influenced adaptation strategies. This factor was considered among the key determinants of this adaptation strategy. This conclusion meant that small scale farmers' size of land under cultivation influenced this adaptation strategy's uptake. From this finding, it was observed that small scale farmers with smaller pieces of land under cultivation were likely to consider this strategy much more compared to the small scale farmers who had more extensive pieces of land. Perhaps small scale farmers with small pieces of land had a great attachment to the crop output than large scale farmers.

The regression analysis further revealed a significant relationship between monthly income and the planting of new resistant/fast-maturing crop varieties. This is because the coefficient of variance $\beta$ was equal to 0.258 (25.8%). This factor was considered among the key determinants of this adaptation strategy. This finding meant that the small scale farmer's amount of income influenced the uptake of this adaptation strategy. From the findings, it was observed that small scale farmers with less income preferred this adaptation strategy compared to higher-income earners.

**Tables 6.9: Level of income and Planting of new resistant/fast-maturing crop variety - Cross tabulation**

| % Within monthly income in Ksh. | New resistant/fast-maturing crop variety | | Total |
|---|---|---|---|
| | Yes | No | |
| <10,000 | 21.1% | 78.9% | 100% |
| 10,001-20,000 | 30.5% | 69.5% | 100% |
| 20,001-30,000 | 30.0% | 70.0% | 100% |
| 30,001-50,000 | 40.9% | 59.1% | 100% |
| >50,0001 | 57.1% | 42.9% | 100% |
| **Total** | **29.0%** | **71.0%** | **100%** |

Source: Researcher 2021

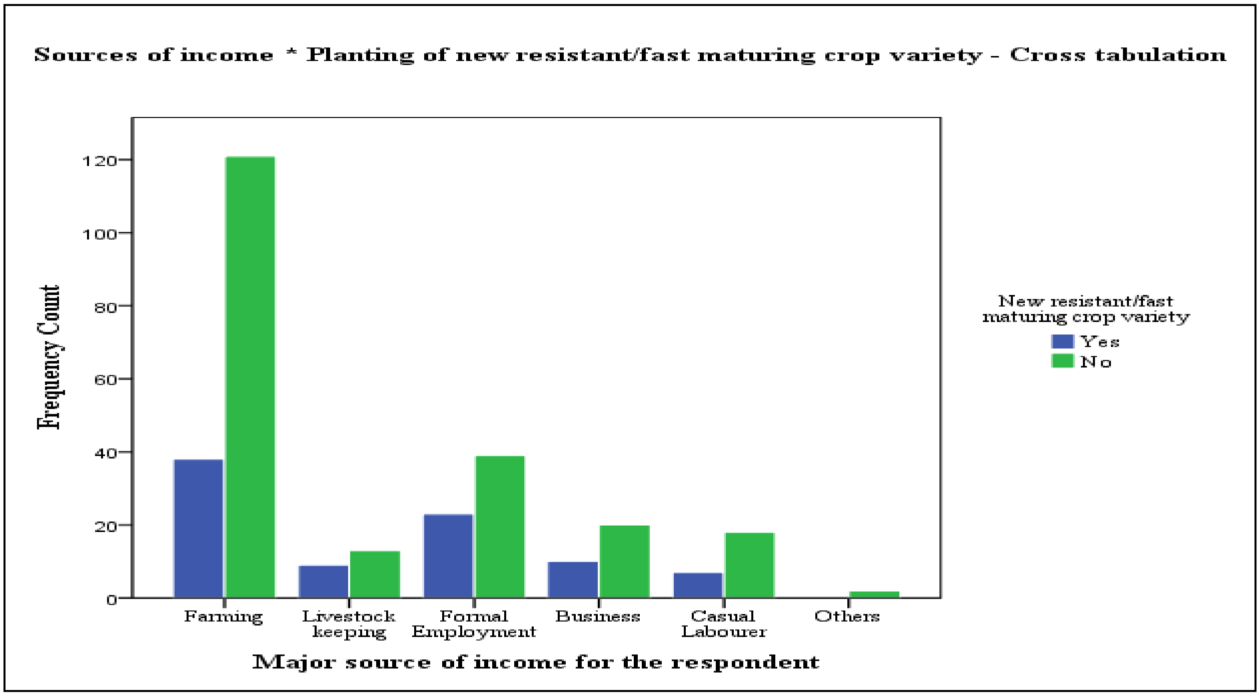



**Figure 6.6: Sources of income * New crop variety - Cross tabulation**

Source: Researcher 2021

Related to these findings, Borel (2009) argued that drought-resistant crops withstand high temperatures and reduced rainfall and still yield good quality output. These factors promote good harvest despite variation in the climate, which leads to access of adequate food and income for the small-scale farming communities.

## 6.7 Adapting to effects of climate variability by changing planting schedules

Table 6.10 presents the findings of the logit model regression associated with this adaptation strategy. The model's predictions were accurate (73.6%) of the adopters and non-adopters of changing planting schedules at a significance of p=0.01. The early onset rains were the preferred choice for beginning planting of maize and Irish potatoes because their seeds require wet conditions for them to germinate. Changes in the onset of rains necessitated a consequential change in planting schedules to mitigate possible crop failures. Three variables, age of the respondents, ownership of land under cultivation, and opinion of the efficiency of the methods for adapting to climatic variability, proved informative on insight regarding farmer's adaptation to changing the specific crop planting periods.

## Table 6.10: Factors influencing small scale farmers' adaptation to adjust planting dates in Nyandarua County

| **The dependent variable is an adaptation to adjusting planting dates (Yes-1)** | | | | | | 95% Confidence Interval for Exp(β) | |
|---|---|---|---|---|---|---|---|
| **Independent variables** | B | Std. Error | Wald | Sig. | Exp(β) | Lower Bound | Upper Bound |
| Intercept | -5.482 | 1.293 | 17.973 | .000 | | | |
| Age of the respondent | .466* | .151 | 9.497 | .002 | 1.594 | 1.185 | 2.144 |
| Respondent's gender | -.061 | .332 | .034 | .855 | .941 | .491 | 1.803 |
| Level of education | .329 | .181 | 3.297 | .069 | 1.390 | .974 | 1.983 |
| Size of the household | .081 | .200 | .162 | .687 | 1.084 | .732 | 1.604 |
| Monthly income in Ksh. | -.141 | .153 | .841 | .359 | .869 | .643 | 1.173 |
| Ownership of land under cultivation | .408* | .118 | 11.896 | .001 | 1.504 | 1.193 | 1.896 |
| Type of farming system | -.091* | .082 | 1.231 | .267 | .018 | .778 | 1.072 |
| Size of land cultivated | -.288* | .155 | 3.464 | .063 | .008 | .553 | 1.015 |
| Changes in crop yields | -.208 | .322 | .420 | .517 | .812 | .432 | 1.525 |
| Effectiveness of the adaptation strategy | .891* | .207 | 18.530 | .000 | 2.439 | 1.625 | 3.659 |
| Model diagnosis | | | | | | | |
| Observations | 300 | | | | | | |
| Log likelihood | 282.85 | | | | | | |
| Wald (LR) Chi square | 73.61 | | | | | | |
| Model significance level | P=0.001 | | | | | | |
| Pseudo $R^2$ | 0.353 | | | | | | |

*Significant at 5% probability level

Source: Researcher 2021

The merits of early planting cannot be overemphasized because crops benefit from the initial drops of rainfall to germinate their seeds faster. As a result, it enhances food security, steady crop yields, and crops' rapid growth. The education of the head of the home positively influenced the decision by the farming families to alter their planting schedules as an adaptation strategy ($\beta$=.329). Higher education suggests that farmers can access and understand agricultural advice given by the extension officers much better than less educated farmers. Education creates awareness among the farmers on the shortcomings of climate related variability on crops and the best way to deal with it.

These results concurred with Hassan and Nhemachena's (2008) findings in their research concerning the determining factors for adjusting to climate variability in Africa, where age was found to have insignificantly influenced farmer’s adaptation to the shocks of climate variability. Still, one could argue that what matters in this relationship is the farming experience and not the farmer's age when it comes to adaptation. This assumption is because farmers with considerable experience were likely to be more successful in adapting to climate variability.

Further assessment of the respondent's opinion on which gender contributes to a greater role in coping with climate variability revealed that women were mainly affected by reduced crop yields (63.3%). Women are essential to making sure that members of the household and especially children acquire daily food ($\beta$=-.061). Contrary to the above statement, men play a more significant role in coping with climate variability (65%) due to their decision-making, asset ownership, and control of a more substantial portfolio within the household and community. The knowledge generated by this finding is that this conflicting gender context hinders women's utilization of various adaptation strategies, particularly the early preparation of land and altering the planting schedules.

The findings of this study about gender influence on adaptation strategies contradicted the results of Ngigi et al. (2017), which indicated that a more significant proportion of women were found to embrace crop-related adaptation strategies than men.

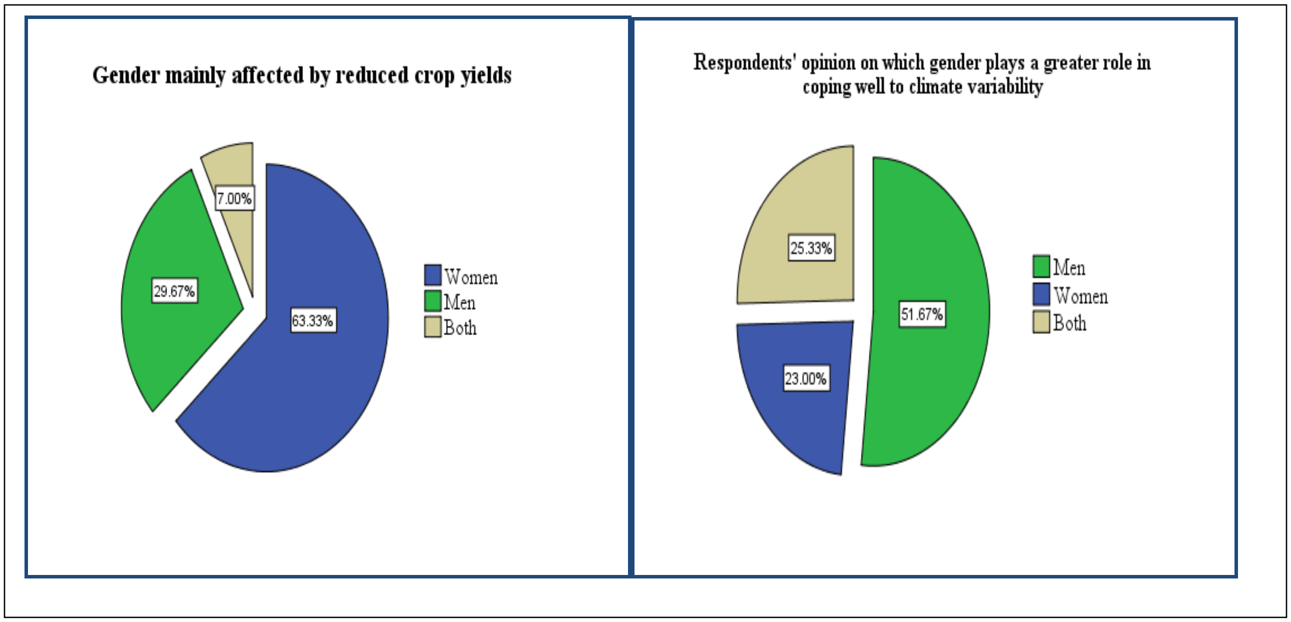



**Figure 6.7 Gender contexts in climate variability and adaptation strategies**

Source: Researcher 2021

The size of the farm land under crop cultivation negatively ($\beta$=-0.288, p=0.008) affected farmers' preference of altering planting schedules as an adaptation strategy. In comparison to farmers with a limited size of land under cultivation, those who owned and controlled large tracts of lands under crop cultivation responded well to altering crop planting dates. In some areas of the land, the large farm size made it easier to adjust planting dates. Farmers' decisions to modify crop planting dates as a climate response adaptation strategy were influenced negatively ($\beta$ =-0.091, p=0.018) by the agricultural system. Many farmers who engaged in rain-fed crop production may have preferred the strategy of adjusting the planting dates as a method of adaptation, regardless of the sort of agricultural system they used.

Farmers in East African countries chose to change field preparation or planting dates to prevent climate-related risks, according to similar studies (Kelvin et al., 2016). It's probable that this is due to the fact that such methods involve little expenditure. This approach entails merely gathering information and teaching small scale farmers on the best timings, whereas many other practices necessitate significant time and financial investment. The results further concurred with another similar study in southeast Nigeria, where agronomists with larger farmlands adapted better than their counterparts with smaller farms (Ozor et al., 2012). These results implied that the size of the household determined the size and proportion of land under cultivation which in turn influenced changing of planting dates depending on the seasonal changes of climate.

**Table 6.11: Size of land under cultivation and Planting of new resistant/fast-maturing crop variety - Cross tabulation**

| **% Within the size of land under cultivation** | **New resistant/fast-maturing crop variety** | | **Total** |
|---|---|---|---|
| | Yes | No | |
| <2 acres | 21.4% | 78.6% | 100% |
| 2-5 acres | 25.3% | 74.7% | 100% |
| 5-10 acres | 42.9% | 57.1% | 100% |
| >10 acres | 31.8% | 68.2% | 100% |
| Total | 29.0% | 71.0% | 100% |

Source: Researcher 2021

## 6.8 Adaptation to climate variability through Income diversification

The term income diversification defines the ability to have multiple streams of income and revenues. This is an increasingly important non crop related adaptation strategy among many households living in rural areas to manage environmental risk. The primary data indicates that small scale` farmers primarily source their income from agricultural activities, mainly contributing approximately 60% of the total household income. Table 6.13 verifies that farming (agricultural crop production) remains the most popular source of income and revenue for the participants. Approximately 53% of the households in the surveyed group gained their income from farming.

### Table 6.12 Sources of revenues for the participants;

| Source of income | Frequency | Per cent | Cumulative Percent |
|---|---|---|---|
| Farming | 159 | 53.0 | 53.0 |
| Formal Employment | 62 | 20.7 | 73.7 |
| Business | 30 | 10.0 | 83.7 |
| Casual Labour | 25 | 8.3 | 92 |
| Livestock keeping | 22 | 7.3 | 99.3 |
| Others | 2 | .7 | 100 |
| **Total** | **300** | **100.0** | |

Source: Researcher 2021

Based on income diversification, the logistic regression statistical model described some determinants of having several streams of income and revenue sources. Table 6.13 illustrates that the household head's higher level of education positively impacted having several income streams per household ($\beta=0.491$, $p=0.048$). Similar studies by UNFCCC (2018) explained the findings by associating high education levels with different economic activities; that is, higher education levels engaged the group with increasingly diversified activities, which contributed to increased chances of earning more income. The findings also acknowledge a high probability of diversifying income sources in families with a small proportion of children to the elderly. The logic applied asserts that households with fewer children significantly reduced the number of members engaged in agricultural production ($\beta=0.445$, $p=0.044$).

**Table 6.13 Factors influencing small scale farmers' adaptation to Income diversification in Nyandarua County**

| **The dependent variable is an adaptation to income diversification (Yes-1)** | | | | | | 95% Confidence Interval for Exp(β) | |
|---|---|---|---|---|---|---|---|
| **Independent variables** | B | Std. Error | Wald | Sig. | Exp(β) | Lower Bound | Upper Bound |
| Intercept | -8.128 | 1.934 | 17.662 | .000 | | | |
| Gender of the respondent | -.167 | .495 | .113 | .736 | .846 | .320 | 2.235 |
| Age of the respondent | .445* | .221 | 4.068 | .044 | 1.560 | 1.013 | 2.404 |
| Monthly income in Ksh. | .017 | .208 | .007 | .934 | 1.017 | .677 | 1.528 |
| Level of education | .491* | .248 | 3.920 | .048 | 1.634 | 1.005 | 2.656 |
| Size of the household | .335 | .282 | 1.414 | .234 | 1.398 | .805 | 2.429 |
| Ownership of land under cultivation | .115 | .185 | .389 | .533 | 1.122 | .781 | 1.611 |
| Type of farming system | .091 | .117 | .604 | .437 | 1.095 | .871 | 1.377 |
| Quantity of land under farming | -.049 | .222 | .048 | .826 | .952 | .617 | 1.471 |
| Changes in crop yields | .790 | .469 | 2.832 | .092 | 2.203 | .878 | 5.526 |
| Effectiveness of the adaptation strategy | .631* | .300 | 4.415 | .036 | 1.880 | 1.043 | 3.388 |
| **<u>Model diagnosis</u>** | | | | | | | |
| Numbered observations | 300 | | | | | | |
| Log likelihood | 149.27 | | | | | | |
| Wald (LR) Chi square | 34.52 | | | | | | |
| Model significance level | P=0.221 | | | | | | |
| Pseudo $R^2$ | 0.27 | | | | | | |

*Significant at 5% probability level

Source: Researcher 2021

According to the findings, there was a higher likelihood of income diversification adoption among farmers with higher levels of education. Additionally, as an adaptation to climate unpredictability, income diversification had a positive coefficient of change, suggesting a positive association between education and income diversification.

In addition, increase in farmer's age decreased the probability of diversifying income sources. Experienced farmers, due to age, are less likely to diversify their sources of income, unlike the aged farmers. These results contradicted the findings of Di Falco (2014), where experienced farmers, due to age, were most certainly had additional revenue streams to supplement the income received from crop farming.

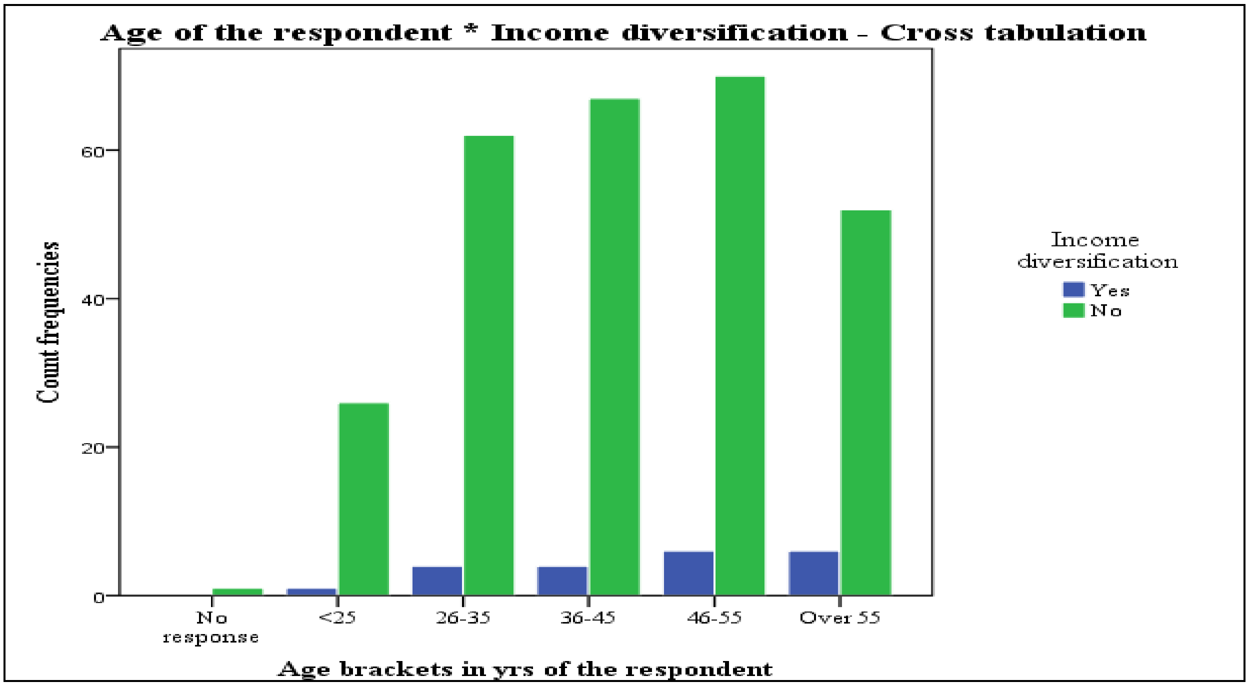



**Figure 6.8: Age of the respondent * Income diversification - Cross tabulation**

Source: Researcher 2021

Deressa et al., (2010) found that the elderly farmers may have been more experienced in farming because they were extensively exposed to previous and present climatic conditions while using the Heckman model in Ethiopia's Nile basin. They concluded that age was a direct contributor to the adaptation strategy employed by farmers. Simotwo et al.'s (2018) recent research in Kenya's Trans-Mara East Sub-County revealed that age as a demographic factor was a more significant determinant of farming activity and manipulation of coping strategies in Kenya's republic.

As far as gender is concerned, 7.3% of male and 6.4% of female respondents reported having used this adaptation strategy. 93% of respondents did not consider this adaptation strategy. This finding indicates that it was not a popular adaptation method among both genders.

These findings contradicted the results of Ngigi et al. (2017) in that effective adaptation strategies depend on gender interaction with access to information, asset ownership, and control of resources, among others. Further research and more investigation should be done to find out this outcome.

**Table 6.14 Gender of the respondent and Income diversification - Cross tabulation**

| **% within Gender of the respondent** | **Income diversification** | | **Total** |
|---|---|---|---|
| | Yes | No | |
| Male | 7.3% | 92.7% | 100% |
| Female | 6.4% | 93.6% | 100% |
| **Total** | **7.0%** | **93.0%** | **100%** |

Source: Researcher 2021

The regression model analysis established that Income diversification as an adaptation strategy was not significantly associated with income level. It was highly anticipated that small scale farmers with low-income levels would diversify their sources of revenue. However, this was not found to be accurate. Farmers with a more comprehensive source of income or high-income levels were more probable to adopt climate variability adaptation than those with low-income levels (Limo, 2013). Mwangi et al. 2020 concluded that farmers near urban centres have relatively high adaptive capacity than those in the country's interior parts. This finding was attributed partly to the accessibility of social amenities, good infrastructure, and other socio-economic factors.

Likewise, income diversification as an adaptation strategy was not statistically associated with the level of education. The regression test results established no association between these two variables. This result was interpreted to mean that education level did not influence the small scale farmer's decision to diversify their sources of income. Mudzonga (2012) observed that education strongly correlated with adapting to climate variability when assessing similar adapting technologies in Chivi district of Zimbabwe. He noticed differences in the farmers' likelihood of familiarising themselves with climate variability dependent on their level of education. Low education levels may severely limit the community's capacity to apply and execute adaptation concepts by limiting the range of viable adaptation responses and interventions. This is according to additional research published by the IPCC in 2014.

Unlike the current investigation, Limo's (2013) observations of the logistic regression confirmed that education has a major role in affecting the adaptability of farming. Age, gender, and farm size were not statistically significant determinants of adjustments in similarity. It is envisaged that the current study's results differed from Limo's (2013) study due to differences in regions and types of crops used.

## 6.9 Conclusion

Results of the research suggests that there was very little or no connection between the variable of age and any of the adaptation strategies. Empirical studies in this discourse have placed the age of the farmers as a critical adaptation strategy determinant and have been associated with experience in crop cultivation and coping well with climate variability. Elderly farmers are perceived to have great experience in applying various adaptation strategies due to exposure to past and present climatic conditions. Indeed, the farmer's age has an important effect on agronomic techniques applied in crop farming.

Other studies show that young farmers adopt modern farming methods quickly, while older farmers tend to retain traditional methods. Older farmers may struggle with scientific farming due to illiteracy and tradition, and may be less energetic. However, adaptation strategies are not significantly associated with age, as access to necessary resources determines effective practices. Older farmers excel in agricultural adaptation activities with availability of capital and land.

The study findings acknowledged that the small-scale farmers in Nyandarua County had achieved substantial levels of literacy and education, which contributed positively to adaptation options. Further assessment of the respondent's opinion on which gender played a more significant role in adjusting and coping with effects of climate variability revealed that women were the ones mainly affected by reduced crop yields (63.3%). Besides, men were considered to play a bigger part in addressing climate variability issues (65%) due to their decision-making and asset ownership within the household and community. The four common adjustment techniques with a high preference by the target farmer group in Nyandarua County were found to be; crop diversification, planting new resistant crops that are fast maturing, adjusting planting dates, and greenhouse farming technology. These adaptation strategies were related to crop farming as one of the leading economic activities in the region of study. The multinomial regression analysis and tests revealed no relationship between the two demographic factors of age and gender in the choice of an adaptation strategy. However, the proportion of land under cultivation, level of income, and education influenced the adoption of the planting of new crop varieties that are fast maturing and able to cope with varying climatic changes. The proportion of land under cultivation, levels of income and education were the most critical factors influencing the uptake of crop farming adaptations.

# CHAPTER SEVEN

# EVALUATION OF CROP FARMING ADAPTATION STRATEGIES TO CLIMATE VARIABILITY

## 7.1 Introduction;

This chapter evaluates the effectiveness of the key adaptation strategies on crop farming agriculture to climate variability. The hypothesis that adaptation strategies and techniques by small scale farmers to climate variability had not significantly increased maize and Irish potato output is tested. The chapter begins by describing the respondents' perception of whether the adaptation strategies employed were effective in improving the crop output or not. The chapter further describes and presents an assessment tool using the empirical crop output and the Multinomial Logistic Regression frameworks to evaluate the effectiveness of climate variability adaptation strategies on selected crop production. MLR, in this case was applied to predict the probability of the selected adaptation strategies being effective or not in improving the crop output among the target group of Nyandarua County. An assessment of crucial informant reviews was also presented to reinforce the results of the empirical crop output and multinomial logistic regression models. The chapter further analysed and evaluated the possible determinants of the key adaptation strategies using the multinomial logistic regression method. Finally, the chapter described the constraints and challenges associated with adopting the critical adaptation strategies for improving the selected crop output. In this chapter, the third hypothesis of the study, which stated that the adaptation strategies utilized by the small-scale farmers to mitigate the negative contributions of climate variability to crop farming had not significantly increased maize and Irish potato output, was tested, and the results presented and discussed before conclusions were made. The chapter concludes with a short and a brief conclusion of issues evaluated and discussed regarding the third objective.

## 7.2 Adaptation strategies relied upon in the area by small scale farmers

As an adaptation approach, 13.1 percent of respondents claimed they had adjusted planting dates. 20.3 percent grew various crop kinds that were considered more tolerant to the effects of climate variation. Most small scale farmers had implemented crop diversification (20.3 percent). Crop irrigation was used by 13.1% of the target participants to increase crop output. In contrast, 4.9 percent considered off-farm jobs as an adaptation technique, i.e. income diversification. Greenhouse technology and crop insurance, with scores of 5.9% and 2.1 percent, respectively, had the lowest levels of adaptability. Other adaptation strategies documented by the study as descriptive replies were employed by 15.2 percent of respondents. Some of the strategies used include; soil conservation, organic farming, crops rotation, mixed farming, expanding cultivatable land areas, and agroforestry. Table 7.1 shows the four most common adaptation strategies subjected to multinomial logistic regression analysis as per the literature review.

### Table 7.1 Respondents reply on adaptation strategies

| **Adaptations strategies;** | **Frequencies** | **Percentages (%)** | **Cumulative frequency %** |
|---|---|---|---|
| *Crops diversification | 91 | 21.21 | 21.21 |
| *Planting new crop varieties | 87 | 20.28 | 41.49 |
| Other methods of adaptation | 65 | 15.15 | 56.64 |
| *Adjusting planting dates | 59 | 13.75 | 70.39 |
| Use of crop irrigation | 53 | 12.35 | 82.74 |
| Greenhouse technology | 24 | 5.59 | 88.33 |
| *Income diversification | 21 | 4.90 | 93.23 |
| No response | 20 | 4.66 | 97.89 |
| Crop insurance policies | 9 | 2.1 | 99.99 |
| **Total** | **429** | **100** | |

- ***Adaptations strategies subjected to multinomial logistic regression analysis
- Notes: Multiple responses were reported

Source: Researcher 2021

## 7.3 Evaluating the crop farming adaptation strategies using the Empirical Crop Output Model

The Empirical crop output model estimated the crop output relationship based on the empirical time series of certain climatic variables using a panel data set of spatial and temporal locations. Since the empirical crop output model utilized in this research was based on long time series of data, i.e., 21 years, it was challenging to model the adaptation strategies under investigation to evaluate their effectiveness in contributing to crop output from time to time. However, despite this limitation, the autonomous adaptation strategies taken by the small scale farmers could be implicitly accounted for, especially when the selected crop output trend was compared with integrated adaptation strategies with other crop management input variables such as fertilizer application, pest, and disease control. One of the most significant limitations of this model was that it lacked the empirical evidence to relate the relationships and inter relationship between the two factors, i.e., the increase in crop output and the adaptation strategies employed. This meant that it relied heavily on physical association and the assumption that an increase in crop output was associated with the proper application of specific adaptation strategies. Because of this reason, the model could not be used effectively to test the particular null hypothesis that adaptation strategies by target participant group to climate variability had not significantly increased maize and Irish potato yields and output. This study's empirical crop output model was presented as a chart showing the variation, trend, and five-year moving averages.

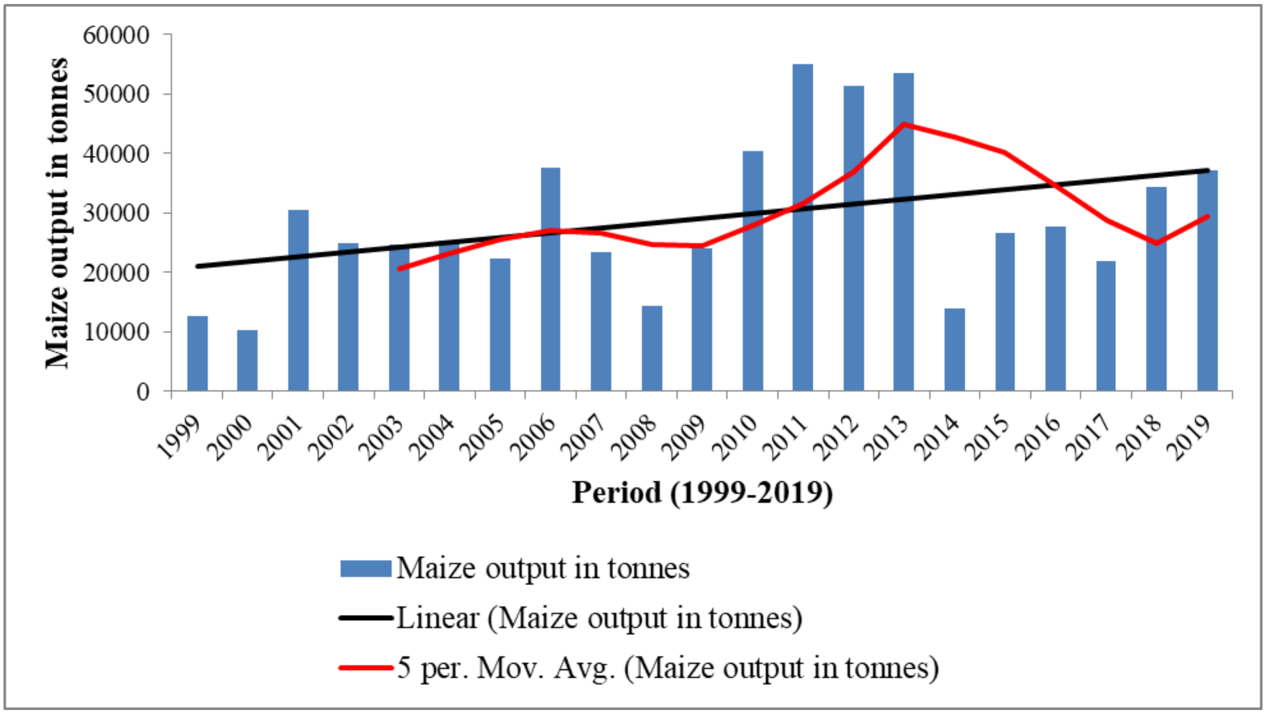



**Figure 7.1: A bar graph showing the trend in maize output and five-year moving average (1999-2019)**

Source: Researcher 2021

The above empirical analysis exhibited that the yield output of maize for the last 21 years had increased. This is because the trend line for this variation was positive. Likewise, the five-year moving average showed a five-year decrease followed by a five-year exponential increase in maize output. The above empirical analysis also indicates that there was a significant and consistent increase in maize output between the year 2015 (26,576 tonnes) and 2019 (37,184 tonnes). This period was the five year preceding the study which was associated with the five-year moving average reflecting a five-year exponential increase in maize output. According to the accurate recalling and reporting by the respondents, the same period had seen many small scale farmers engage in rigorous application of the various crop related adaptation strategies. The exponential increase in maize output was therefore associated with proper application of the adaptation measures within the same period of 2015 to 2019.

These results concluded that the adaptation strategies applied within 21 years effectively maintained and improved the crop yield and output. Further analysis also indicated a significant increase in maize output two years preceding the study. This increase was further supported by the fact that the adaptation strategies employed within this duration contributed to the increase in the output. In situations where there was a decrease in crop output, other factors beyond the adaptations like the severity of climatic factors were presumed to have played a part.

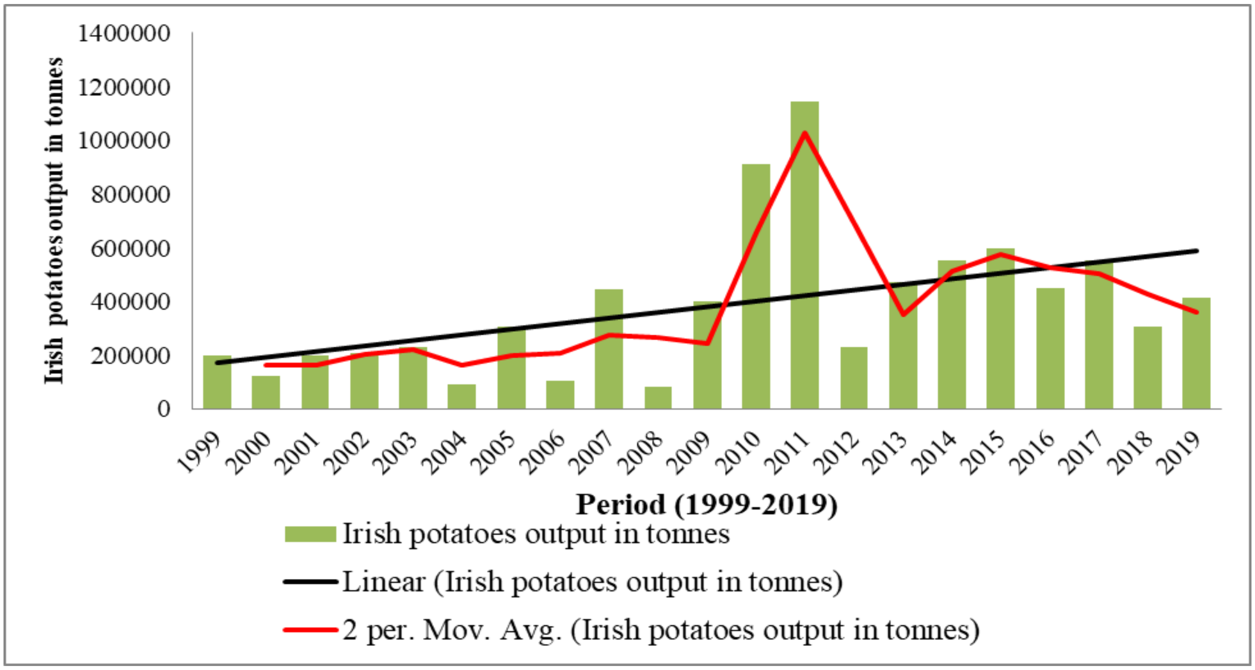



**Figure 7.2: A bar graph showing the trend in Irish potatoes output and two years moving average (1999-2019)**

Source: Researcher 2021

From the above empirical analysis of Irish potato output, two years moving average indicated that a significant increase followed a decrease in Irish Potato output. The consistency of two years increase in the output of Irish Potato for the period of 2000-2001, 2002-2003, 2010-2011, 2012-2013, 2013-2014, 2014-2015, 2016-2017 and 2018-2019 was depicted well by the general positive trend line for the entire period as presented by the empirical analysis in figure 7.2.

Basing the argument of 2 years accuracy recalling and reporting, small scale farmers reported to have adapted in one way or another to the varying climatic trends. This positive reporting between 2018 and 2019 was therefore associated with increase in Irish potato output between 2018 (305,250 tonnes) and 2019 (413,160 tonnes). The trend line for variation in Irish Potato output was also positive, indicating that the output of Irish potato had registered a rising pattern during the previous 21 years. The two years preceding the study were noted to have registered an increase in Irish potato output. These positive indicators of improving Irish potato output were linked to adaptation strategies employed within 21 years.

Since the recalling ability among the small scale farmers may not extend beyond a long time, the last two years preceding the study were considered the best predictor that the adaptation strategies employed were effective in improving the crop yields and output. However, climatic extremes may have empowered the farmer's adaptation decisions and capacity, which could have led to a significant decrease in Irish potato output, i.e., 2011 and 2012.

Comparing the empirical results of the two crops' output suggests that the adaptation strategies may have worked better in Irish potatoes than in maize crops. This is because the trend line in Irish potatoes was much stronger than maize output. In addition, the variation in Irish potatoes output was better illustrated in two years moving average, unlike maize output, which was illustrated using the five-year moving average. This is even though the average output of Irish potatoes in tonnes was much higher than that of maize. A significant limitation of this model was that it could not single out the adaptation strategies that were more effective than others. Because of this weakness, there was a need to subject the adaptation strategies to a more complex statistical tool to establish their relationship with farmers' opinions about their efficacy in improving the output of the crops.

## 7.4 Perception about the effectiveness of the applied adaptation techniques

Several adaptation strategies have been adopted in response to varying climatic factors based on how small scale farmers perceived the effects and influences of climate variability. About 72% of the household respondents said they had responded to climate variability in specific ways. Around 27% said they had not, while 1% of the respondents were unsure about the question.

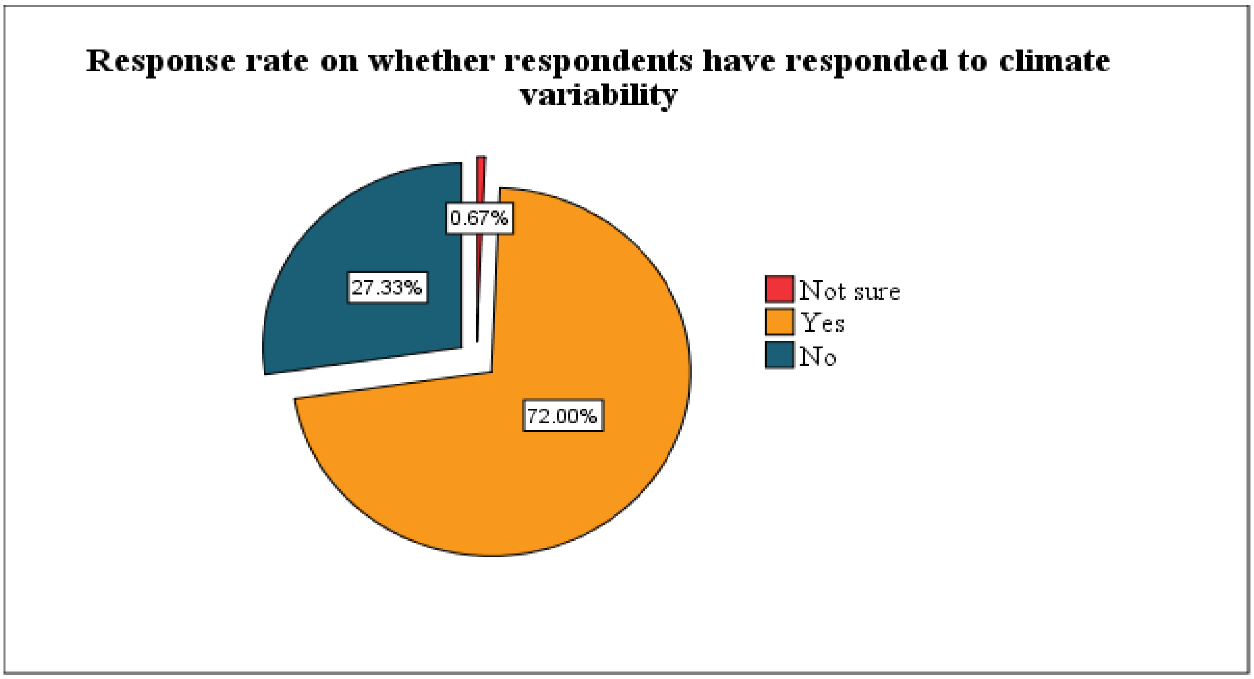



**Figure 7.3 Respondent’s response to climate variability**

Source: Researcher 2021

According to Belehu T. (2005), existing coping strategies must be examined for efficacy and sustainability regarding prospected improvement in crop yields. Regarding respondents' views on the efficacy of the adaptation tactics to improve crop output, this study showed that 61.33% of small scale farmers reported that some adaptation measures were effective for some time. However, 20.67% of respondents reported that the adaptation strategies adopted were ineffective, while 18% failed to respond to this question. It was assumed that the non-response came from farmers who reported not having undertaken any adaptation strategy or did not understand whether what they were doing in the farms was adaptation.

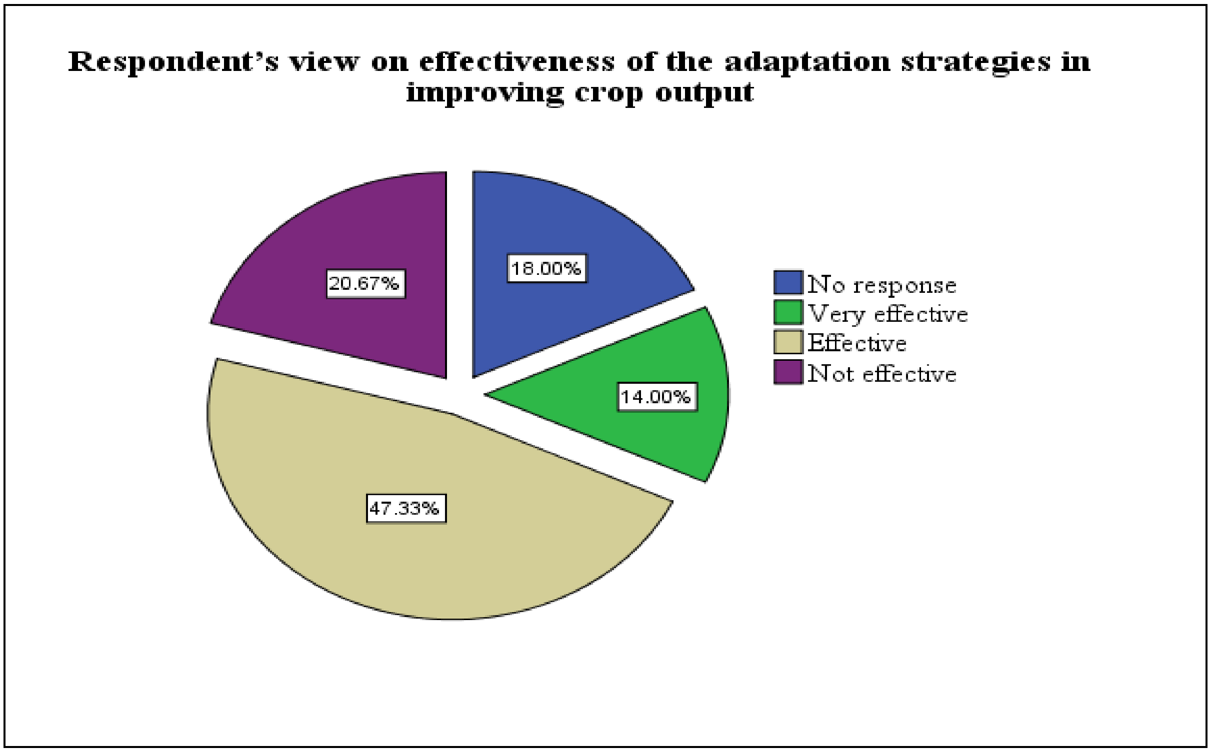



**Figure 7.4 Respondent's view on the efficacy of the adaptation tactics to improve crop output**

Source: Researcher 2021

## 7.5 Relationship between key adaptation strategies and the perceived efficacy among the small scale farmers

Descriptive statistics showed that crop diversification was the most preferred form of adaptation among the target participant group in Nyandarua County (21.21%). This was followed by planting new crops variety and adjusting planting dates relative to changes in climatic patterns (20.28% and 13.75% in that order). In addition, when the respondents were questioned to give their views on whether adaptation strategies were effective or not, Crop diversification and planting of a new variety of crops again scored the highest (80.4% and 75.9%, respectively)

Regarding evaluating the efficacy of the four selected adaptation strategies based on the small scale farmers' perceptions, many farmers felt that the strategies undertaken were effective (56.6%), 15.5% very effective, and 25.5% ineffective. However, six respondents (2.4%) who had taken at least one of the four adaptation strategies evaluated declined to answer the related question. Perhaps this could have resulted from the question's ambiguity or lack of clarification on the expected response, especially when the researcher's assistants were not available to guide the respondents.

In conclusion, the preliminary finding from the above descriptive statistics and the cross-tabulations (table 7.2) revealed that the adaptation strategies the small scale farmers applied; effectively improved the specific crop yields and output. However, this mere descriptive illustration was not enough evidence to conclude that the four adaptation strategies were effective. Therefore, a more scientific statistical method was necessary to confirm this situation and test the null hypothesis.

## Table 7.2 Cross tabulations of the key adaptation strategies and their efficacy frequencies by the small-scale farmers

| Perceptions about the efficacy of adaptations techniques applied by small-scale farmers | Crops diversification | New crops variety | Adjusting planting dates | Income diversification | Total |
|---|---|---|---|---|---|
| No response | 2 (2.3%) | 1 (1.1%) | 2 (3.6%) | 1 (4.8%) | 6 (2.4%) |
| Very effective | 15 (17.2%) | 16 (18.4%) | 7 (13%) | 1 (4.8%) | 39 (15.5%) |
| Effective | 55 (63.2%) | 50 (57.5%) | 24 (43%) | 13 (61.9%) | 142 (56.6%) |
| Not effective | 15 (17.2%) | 20 (23.0%) | 23 (41.1% | 6 (28.6%) | 64 (25.5%) |
| **Total** | **87 (100%)** | **87 (100%)** | **56 (100%)** | **21 (100%)** | **251 (100%)** |

Source: Researcher's computations (2021)

## 7.6 Evaluating the effectiveness of the critical adaptation tactics using the Multinomial Logistic Regression Model

In order to establish the efficacy of the four key adaptation strategies, the study applied the Multinomial regression model to evaluate the selected adaptation strategies against the perceived outcome of whether they were effective or not effective in improving the crop yield and output. Multinomial logistic regression is a model utilized in evaluating the relationships between the categorical dependent variable and more independent variables. The model accomplished the stated objective by estimating the possibility of different outcomes of categorically distributed dependent variables given a set of independent variables, which may also have been categorical. The independent variable, in this case, was whether the adaptation strategies were very effective, effective, or not effective. These predicted outcomes were categorical and not ordered. Conversely, the dependent variables were the four adaptation strategies, i.e., crops diversification, new crop variety, income diversification and adjusting planting dates. The dependent variables were categorical, i.e., applied or not applied (Yes or No) and not ordered. These unique data characteristics made the Multinomial logistic regression analysis an inferential statistic that was suitable for this associated hypothesis testing. In this case, each adaptation strategy under investigation was evaluated against the small scale farmer's perception of whether it was effective or not while holding the other adaptations constant. Therefore, this statistical tool enabled the researcher to separate and single out the adaptation strategies according to how effective they were in promoting crop yields and output in responding to climate variations.

The findings of the multinomial regression analysis and technique demonstrated that taking up crop diversification as an adaptation measure effectively increased crop output. This is because the Exp data odds ratio (Exp (β)) for the two predicted outcomes of either very effective or effective was more than one, i.e. (Exp (β) =1.741 and Exp (β) =1.981, respectively. Crop diversification defines the growing of several crops in a defined geographical area. It is possible to achieve this strategy by introduction of new crop species or types, as well as altering the current cropping system. In Kenya, the Irish potato is an excellent choice for crop diversity. The tuber is already a primary or secondary food source for many rural communities. Potatoes have a good amino acid balance and are high in protein, calcium, potassium, and vitamin C.

Furthermore, the Irish potato is a high-yielding crop. Maize, rice, and wheat all generate less food quantity than Irish potatoes as evaluated against time and unit of land. Its vegetative cycle is quick and adaptive, and it is possible to harvest the crop after 100 days. Additionally, the crop has extra ordinary resilience to nearly all climatic and altitude conditions, even growing in dry and semi-arid environments. Moreover it allows for intercropping and crop rotation with a variety of other food and cash crops, including wheat, maize, and barley. Likewise, applying new crop varieties as an adaptation strategy was also effective. New crop varieties included the following drought-resistant hybrid maize variety; DH01, DH02, DH04, DH08, H532, H164D, H628, H513, H516, and H517; Modern varieties of Irish potatoes such as Annet, Asante, Desiree, Kenya Baraka, Shangi, etc. are considered to be drought-sensitive. The efficacy of this adaptation strategy was because the Exp data odds ratio (Exp (β) for the two predicted outcomes of either very effective or effective was more than one, i.e. (Exp (β) =1.292 and Exp (β) =1.141, respectively. However, these two logistic statistical tests at P=0.05 were not statistically significant. This meant that the responses for these two adaptation strategies were not good predictors of the outcome of whether they were effective or not.

Regarding adjusting planting dates as an adaptation strategy, the multinomial logistic analysis revealed that this adaptation strategy was less effective. This is because the Exp data odds ratio

(Exp (β)) for the two predicted outcomes of either very effective or effective was less than one, i.e. (Exp (β) =0.339 and Exp (β) =0.345, respectively. Early planting date for maize could benefit high yields. However, there was no evaluation of the planting date influence on high-yielding crops because data was not available at the time. One of the primary aspects to consider for high-yielding maize output has been the intelligent utilization of the planting date window, which lengthens the growing season while exploring ideal conditions at critical crop growth phases.

Ngetich et al. (2011), while studying the effects of planting dates in central Kenya, observed no significant effect on maize yield during the long rain season of 2010, concluding that rainfall patterns and amounts caused this scenario. Therefore, to optimize yield under variable climatic conditions, it is critical that planting be appropriate to fit with limited multiyear and multi-location replications, growing season, and crop maturity length (Feenstra et al., 2015). Starting a maize farm within the early planting season is better for market and demand reasons. The optimum planting date is between 15$^{th}$ March and 15$^{th}$ April, although planting could be done as soon as rainfall becomes steady. Recently these planting dates have been extended up to 15$^{th}$ May and June due to delay in the onset of rainfall.

Irish potatoes normally take 2 to 3 months to mature after planting. When the foliage begins to turn brown, it is time to begin harvesting. When the earth is dry, harvesting is frequently done. Gently dig up the potatoes from the earth when harvesting to avoid bruises or damage to the tubers. Plant potatoes three weeks before the final cold season, or when the soil temperature four inches deep reaches around 21°C. Potatoes should be sown in most parts of Kenya in February or early March. The tops can be frozen off by frost if planted too early. There are three cycles for adjusting the planting dates of Irish potatoes: early potatoes can be planted as early as mid-March, and early potatoes should be planted a few weeks later. In order to yield a healthy crop, main crop potatoes must remain below the ground longer after planting, which typically occurs in April. There has been a general shift of planting of the Irish potato crop to early June. Main potato crops take approximately 120 days till harvest, while early potatoes record an average of 100 days. Therefore, scheduling the planting season in May and June may improve yield harvest in late July dry periods.

Similarly, income diversification as a spontaneous adaptation strategy was less effective. This is because the Exp data odds ratio (Exp (β)) for the two predicted outcomes of either very effective or effective was less than one, i.e. (Exp (β) =0.228 and Exp (β) =0.941, respectively. Adjusting planting dates logistic tests at P=0.05 were statistically significant while the income diversification tests were not. Other sources of income other than farming for the small scale farmers included formal employment, business, livestock keeping, casual labour, etc.

From the above results, it was concluded that two of the four selected adaptation strategies evaluated were effective. In contrast, the other two were found to be less effective. In this case, the associated null hypothesis was tested on two levels, i.e., the adjustment tactics by the target participants to climatic changes (crop diversification and new crop variety) had not significantly increased maize, and Irish potato output was rejected. On the other hand, these strategies (adjusting planting dates and income diversification) had not significantly increased maize, and Irish potato output failed to be rejected.

## Table 7.3: The Multinomial Logistic Regression analysis table

**Parameters Estimates**

| Crops diversification[a] | | B | Std. Error | Wald | df | Sig. | Exp(β) | 95% Confidence Interval for Exp(β) | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Lower Bound | Upper Bound |
| Yes | Intercept | -1.142 | .297 | 14.832 | 1 | .000 | | | |
| | [Very effective] | .554 | .438 | 1.603 | 1 | .205 | 1.741 | .738 | 4.106 |
| | [Effective] | .684 | .343 | 3.972 | 1 | .046 | 1.981 | 1.011 | 3.879 |
| | [Not effective] | 0[b] | . | . | 0 | . | . | . | . |
| **New crop variety[a]** | | **B** | **Std. Error** | **Wald** | **df** | **Sig.** | **Exp(β)** | **95% Confidence Interval for Exp(β) Lower Bound** | **Upper Bound** |
| Yes | Intercept | -.742 | .272 | 7.458 | 1 | .006 | | | |
| | [Very effective] | .256 | .418 | .376 | 1 | .540 | 1.292 | .570 | 2.932 |
| | [Effective] | .132 | .324 | .167 | 1 | .683 | 1.141 | .605 | 2.152 |
| | [Not effective] | 0[b] | . | . | 0 | . | . | . | . |
| **Adjusting planting dates[a]** | | **B** | **Std. Error** | **Wald** | **df** | **Sig.** | **Exp(β)** | **95% Confidence Interval for Exp(β) Lower Bound** | **Upper Bound** |
| Yes | Intercept | -.528 | .263 | 4.034 | 1 | .045 | | | |
| | [Very effective] | -1.081 | .490 | 4.861 | 1 | .027 | .339 | .130 | .887 |
| | [Effective] | -1.065 | .345 | 9.503 | 1 | .002 | .345 | .175 | .679 |
| | [Not effective] | 0[b] | . | . | 0 | . | . | . | . |
| **Income diversification[a]** | | **B** | **Std. Error** | **Wald** | **df** | **Sig.** | **Exp(β)** | **95% Confidence Interval for Exp(β) Lower Bound** | **Upper Bound** |
| Yes | Intercept | -2.234 | .430 | 27.037 | 1 | .000 | | | |
| | [Very effective] | -1.480 | 1.100 | 1.812 | 1 | .178 | .228 | .026 | 1.964 |
| | [Effective] | -.061 | .519 | .014 | 1 | .906 | .941 | .340 | 2.600 |
| | [Not effective] | 0[b] | . | . | 0 | . | . | . | . |

a. The reference category is: No.

b. This parameter is set to zero because it is redundant.

Source: Researcher 2021

## 7.7 Evaluating the determinants of the key adaptation strategies

Several determinants were assessed based on their relationship to the four key adaptation strategies chosen for the study. These determinants were; Gender of the respondent, Size of the household, Age of the respondent, Level of education, Monthly income in Ksh., Ownership of land, Size or proportion of land under cultivation, Type of farming system, Changes in crop yields and Effectiveness of the adaptation strategy.

### 7.7.1 Adjusting to climatic variability through crop diversification

In Nyandarua County, a number of variables affected farmers' decision to use crop diversification as a long-term adjustment tactic to climate unpredictability. The significance of the multinomial regression model was at $p<0.01$ in indicating the socio economic determinants of adoption of crop diversification strategies by the farmers, and predicted 87.6% of adopters. The farmers' choice of this adaptation technique of crop diversification was explained in part by their perception of the efficacy of this adaptation technique. The farmers' preference of technique to crop diversification in the research area as indicated in table 7.4 was not explained by any of the other components.

**Table 7.4: Factors influencing small scale farmers' adaptation to crop diversification in Nyandarua County**

| **The dependent variable is adoption crop diversification (Yes-1)** | | | | | | 95% Confidence Interval for Exp(β) | |
|---|---|---|---|---|---|---|---|
| **Independent variables** | B | Std. Error | Wald | Sig. | Exp(β) | Lower Bound | Upper Bound |
| Intercept | -1.556 | .956 | 2.652 | .103 | | | |
| Gender of the respondent | .155 | .274 | .319 | .572 | 1.167 | .682 | 1.997 |
| Age of the respondent | -.012 | .114 | .012 | .914 | .988 | .789 | 1.236 |
| Size of the household | -.103 | .174 | .351 | .554 | .902 | .642 | 1.268 |
| Level of education | .108 | .152 | .502 | .479 | 1.114 | .826 | 1.501 |
| Monthly income in Ksh. | .067 | .122 | .302 | .583 | 1.069 | .842 | 1.358 |
| Size of land under cultivation | .103 | .127 | .650 | .420 | 1.108 | .863 | 1.422 |
| Ownership of land | -.185 | .111 | 2.772 | .096 | .831 | .669 | 1.033 |
| Type of farming system | .153 | .066 | 5.346 | .021 | 1.166 | 1.024 | 1.328 |
| Changes in crop yields | -.118 | .275 | .184 | .668 | .889 | .519 | 1.523 |
| **Effectiveness of the adaptation strategy** | **.378*** | **.142** | **7.110** | **.008** | **1.460** | **1.105** | **1.927** |
| Model diagnosis | | | | | | | |
| Observations | 300 | | | | | | |
| Log likelihood | 352.29 | | | | | | |
| Wald (LR) Chi square | 87.6 | | | | | | |
| Model significance level | P=0.003 | | | | | | |
| Pseudo $R^2$ | 0.167 | | | | | | |

*Significant at 5% probability level

Source: Researcher 2021

The efficacy of this adaptation strategy positively ($\beta=0.378$, $p=0.008$) impacted farmers' choice to use crop diversification as a desirable technique to mitigate and adjust to the effects of climate change and variability. Small scale farmers who perceived this adaptation strategy as effective adapted to crop diversification more than small scale farmers who did not perceive it as effective. This may have been attributed to by the fact that the adaptation strategy could have improved the crop yield regardless of the climatic changes experienced in the County. Results from table 7.4 above indicate and confirms that the respondents' gender, level of education, and type of farming system were more positively significant in influencing crop diversification, while the respondent's age was the least significant.

### 7.7.2 Adaptations to climate variability through the planting of new resistant and drought tolerant crop variety

The significance of the statistical framework utilized was at $p<0.01$ and accurately projected 62.23% reliance on adjusted farming strategies for both adopters and non-adopters to the drought-resistant crop farming techniques in Nyandarua County. This was according to a logistic regression evaluation of the elements influencing small scale farmers' adaptation of new varieties of crops tolerant to climate variability, as shown in Table 7.5. However, all the variables apart from the efficacy of the adaptation strategy were insignificant in explaining the adoption of this adaptation strategy in Nyandarua County. The efficacy of these adaptation measures in influencing agricultural yield was consistent with a research that proposed the cultivation of more suited and resilient crop types as a drought-resilient strategy to lessen climate variability's effects in Africa (IPCC, 2007). The finding was also backed up by a research carried out in Vihiga, where the researchers found that improved livestock feed and breeds, together with average yields for dual-purpose sweet potato types, would fully counter balance the effects of climate fluctuation (Kelvin et al., 2016). Another study discovered that introducing drought-tolerant cultivars to Ghana farmers would boost maize harvest (Tachie-Obeng et al., 2012).

In Nyandarua County, the common highland maize variety adopted by many farmers was H614D. This variety does well at an estimated altitude of between 1500 and 2800 metres above sea level. This common hybrid variety takes 160-210 days to mature with an approximate yield of x90KG/acre of 38 bags. Small scale farmers attributed this maize variety to a sweet-tasting, high density, long storage period, and resistance to grey leaf spots and blight. Modern varieties of Irish potatoes in Kenya and Nyandarua, in particular, are considered drought-sensitive. These varieties include Annet, which requires a medium-high altitude of 1300-2000 m.a.s.l. This has a short maturity period of (≤ 3 months) with a medium output yield of (30-35 tons/ha). Desiree necessitates a high altitude of 1800-2600 meters above sea level. It has a 2.5-3.5 month early to medium maturity time and a medium to high output yield of 35-40 tons/ha. Desiree is a medium-tall erect cultivar characterized by dark green leaves, sized at approximately 0.7 meters in height, a sturdy stem, and has a small number of flowers that are pale pink in colour. The crop has demonstrated high degree of tolerance to Potato Virus Y (PVY) disease.

**Table 7.5 Factors influencing small scale farmers' adaptation to new resistant crop variety in Nyandarua County**

| **The dependent variable is the adoption of a new crop variety (Yes-1)** | | | | | | 95% Confidence Interval for Exp(β) | |
|---|---|---|---|---|---|---|---|
| **Independent variables** | B | Std. Error | Wald | Sig. | Exp(β) | Lower Bound | Upper Bound |
| Intercept | -2.212 | .973 | 5.165 | .023 | | | |
| Age of the respondent | -.003 | .116 | .001 | .978 | 1.003 | .799 | 1.260 |
| Gender of the respondent | .038 | .281 | .019 | .892 | 1.039 | .599 | 1.801 |
| Size of the household | -.088 | .173 | .261 | .609 | .915 | .652 | 1.285 |
| Level of education | .165 | .153 | 1.165 | .280 | 1.180 | .874 | 1.593 |
| Monthly income in Ksh. | .258 | .122 | 4.433 | .035 | 1.294 | 1.018 | 1.645 |
| Ownership of land under cultivation | -.028 | .106 | .070 | .791 | .972 | .791 | 1.196 |
| Size of land under cultivation | -.284 | .128 | 4.973 | .026 | 1.329 | 1.035 | 1.706 |
| Type of farming system | .098 | .067 | 2.158 | .142 | 1.103 | .968 | 1.257 |
| Changes in crop yields | -.273 | .273 | 1.004 | .316 | .761 | .446 | 1.299 |
| **Effectiveness of the adaptation strategy** | **.506*** | **.151** | **11.200** | **.001** | **1.659** | **1.233** | **2.232** |
| Model diagnosis | | | | | | | |
| N of observations | 300 | | | | | | |
| Wald (LR) Chi square | 62.23 | | | | | | |
| Log likelihood | 353.67 | | | | | | |
| Model significance level | P=0.000 | | | | | | |
| Pseudo $R^2$ | 0.598 | | | | | | |

*Significant at 5% probability level

Source: Researcher 2021

### 7.7.3 Changing crop planting dates as a technique of adapting to climate unpredictability

The logic model's outcome is shown in Table 7.6. The model properly predicted that 73.61 percent of adopters and non-adopters would adjust crop planting dates, with a p=0.01 significance level. Maize and Irish potatoes should be planted as soon as the wet season begins.

Changes and delays in the start of the rainy seasons would cause planting dates to be shifted in order to avoid crop failures. Farmers' adaptation to altering specific crop planting times in Nyandarua County was explained by three variables: respondents' age, ownership of land under cultivation, and perception of the efficacy of adaptation techniques to climate variability.

## Table 7.6 Factors affecting small scale farmers' adaptation to adjusting planting dates in Nyandarua County

| The dependent variable is an adaptation to adjusting planting dates (Yes-1) Independent variables | B | Std. Error | Wald | Sig. | Exp(β) | 95% Confidence Interval for Exp(β) | |
|---|---|---|---|---|---|---|---|
| | | | | | | Lower Bound | Upper Bound |
| Intercept | -5.482 | 1.293 | 17.973 | .000 | | | |
| Gender of the respondent | -.061 | .332 | .034 | .855 | .941 | .491 | 1.803 |
| Age of the respondent | .466* | .151 | 9.497 | .002 | 1.594 | 1.185 | 2.144 |
| Size of the household | .081 | .200 | .162 | .687 | 1.084 | .732 | 1.604 |
| Level of education | .329 | .181 | 3.297 | .069 | 1.390 | .974 | 1.983 |
| Monthly income in Ksh. | -.141 | .153 | .841 | .359 | .869 | .643 | 1.173 |
| Type of farming system | -.091* | .082 | 1.231 | .267 | .018 | .778 | 1.072 |
| Size of land under cultivation | -.288 | .155 | 3.464 | .063 | .008 | .553 | 1.015 |
| Ownership of land under cultivation | .408* | .118 | 11.896 | .001 | 1.504 | 1.193 | 1.896 |
| Changes in crop yields | -.208 | .322 | .420 | .517 | .812 | .432 | 1.525 |
| **Effectiveness of the adaptation strategy** | **.891*** | **.207** | **18.530** | **.000** | **2.439** | **1.625** | **3.659** |
| Model diagnosis | | | | | | | |
| Observed Quantities | 300 | | | | | | |
| Loglikelihood | 282.85 | | | | | | |
| Wald (LR) Chisquare | 73.61 | | | | | | |
| Model significance level | P=0.001 | | | | | | |
| Pseudo $R^2$ | 0.353 | | | | | | |

*Significant at 5% probability level

Source: Researcher 2021

Farmers' decisions to modify crop cultivating schedules as an adaptation strategy were negatively influenced by land size under crop cultivation (β=-0.288, p=0.008). In comparison to farmers with a limited quantity of land under cultivation, this meant that farmers owning and controlling large tracts of land under cultivation responded well to altering crop planting dates. In some areas of the land, the large farm size made it easier to adjust planting dates. Farmers' decisions to modify planting schedules were influenced negatively ($\beta=-0.091$, $p=0.018$) by the agricultural system. Farmer's reliance on rain to feed their crop cultivation had a preference of adjusting the planting schedules as an adaptation method, regardless of the sort of agricultural system they used.

Farmers in East African countries chose to change field sowing schedules to prevent climate-associated risks, according to studies by (Kelvin et al., 2016). It's probable that this was due to the fact that such methods involved little expenditure. This approach entails merely gathering information and teaching small scale farmers, whereas many other practices necessitate substantial time and financial investment.

### 7.7.4 Adaptation to climate variability through Income diversification;

The adaptation technique of income diversification refers to increasing the number of different sources of income. Diversification of income is becoming a more essential adaptation strategy for many rural households to mitigate environmental risk. According to source data, small scale farmers mostly earn money through farming, which accounts for 60% of total household income. Crop production (farming) was the most importantly considered source of earnings between the residents. Table 7.7 demonstrates that over 53% of farm households in the sample under study made money from selling crops.

The logistic regression statistical model described certain determinants of some revenue sources based on income diversification. Table 7.7 revealed that the household head's education levels ($\beta=0.491$, $p=0.048$) was strongly correlated with the quantity of revenue sources. According to UNFCCC (2018) studies, high levels of education open the door to a variety of economic pursuits. Better education means being able to participate in a wider range of activities and, as a result, having a greater possibility of earning extra and more money. The findings also indicate that homes with a small number of young children and older persons are typically likely to increase and diversify their revenue sources, as a higher proportion of children means fewer family members can engage in crop related agricultural production (β=0.445, p=0.044).

## Table 7.7 Factors influencing small scale farmers' adaptation to use Income diversification in Nyandarua County

| **The dependent variable is an adaptation to income diversification (Yes-1)** | | | | | | 95% Confidence Interval for Exp(β) | |
|---|---|---|---|---|---|---|---|
| **Independent variables** | B | Std. Error | Wald | Sig. | Exp(β) | Lower Bound | Upper Bound |
| Intercept | -8.128 | 1.934 | 17.662 | .000 | | | |
| Age of the respondent | .445 | .221 | 4.068 | .044 | 1.560 | 1.013 | 2.404 |
| Gender of the respondent | -.167 | .495 | .113 | .736 | .846 | .320 | 2.235 |
| Size of the household | .335 | .282 | 1.414 | .234 | 1.398 | .805 | 2.429 |
| Level of education | .491 | .248 | 3.920 | .048 | 1.634 | 1.005 | 2.656 |
| Monthly income in Ksh. | .017 | .208 | .007 | .934 | 1.017 | .677 | 1.528 |
| Ownership of land under cultivation | .115 | .185 | .389 | .533 | 1.122 | .781 | 1.611 |
| Size of land under cultivation | -.049 | .222 | .048 | .826 | .952 | .617 | 1.471 |
| Type of farming system | .091 | .117 | .604 | .437 | 1.095 | .871 | 1.377 |
| Changes in crop yields | .790 | .469 | 2.832 | .092 | 2.203 | .878 | 5.526 |
| Effectiveness of the adaptation strategy | .631 | .300 | 4.415 | .036 | 1.880 | 1.043 | 3.388 |
| **Model diagnosis** | | | | | | | |
| Number of observations | 300 | | | | | | |
| Log-likelihood | 149.27 | | | | | | |
| Wald (LR) Chi-square | 34.52 | | | | | | |
| Model significance level | P=0.221 | | | | | | |
| Pseudo $R^2$ | 0.27 | | | | | | |

*Significant at 5% probability level

Source: Researcher 2021

## 7.8 Analysis of Key informants review on the efficacy of crop farming adaptation strategies against climate variability

Key informant interviews and rural appraisal were the primary data collection techniques to analyze the essential informants' review on the topic of study. The interviews were conducted after the compilation of the first and second objectives. Twenty key informants and resource persons were selected for the interview. The key informants and resource persons were purposively sampled to include the agricultural extension officers in the area. The researcher perceived them as knowledgeable of the area's past and current trends of climate variability, crop farming, and adaptation strategies.

With changes in rainfall pattern, a key informant indicated that;

*"Rainfall was enough and precisely forecast in the 1980s, but records showed that recently decreased rainfall volumes are borne from a high rate of forest loss that disrupted the climate pattern, e.g. less rainfall across the short and long rains season," Mr. Daniel Muchiri said (Deputy Director of Agriculture-crops-Nyandarua County).*

Key informants uniformly acknowledged that farmers' accessibility to climate variability data from online and print media greatly influenced the agronomists' choice to adapt to climate variability. A key informant indicated that small scale agronomists with access to climate variability data and publications were more likely to adapt and adjust to climatic variability than those ones who did not have access to climate variability information. As one important informant put it:

*"Through my work with small scale farmers, I've noticed that some people listen to farming radio programs and smart agriculture on television as a means of accessing information about climate variability, and as a result, farmers can identify and plan the best time to cultivate their*

*land, plant, and harvest as compared to those who do not." Mr. J. K. Ndung'u is a member of the J. K. Ndung'u Foundation (Agricultural and Mechanization services Deputy Manager-Nyahururu).*

Further interviews with key informants revealed that husbands and wives have varied perceptions of their understanding and knowledge of the main causes and implication of climate variations based on specific elements. *"The former gender felt they had a greater degree of knowledge while wives perceived themselves to be not well educated on the causal factors of climate unpredictability and its impacts on their livelihood," one key informant said. Mr. John Mwangi Wambugu (Crops officer-Agricultural Training Centre-Njabini).*

Because most small scale farmers have little and inadequate knowledge of the causes and mitigation of climate variability, the key informants proposed that further awareness campaigns to be continuously performed in the County.

*"Wives and husbands believed that unproductive farming methods, such as the degradation of wetlands and water reservoirs, were primary causes of climate change. Likewise, most of the wives believed that God or acts of nature caused climate change" Mr. David. Mwaniki (Ward Agricultural Extension Officer-Njabini Ward)*

### 7.8.1 Benefits and costs of crop farming adaptation strategies

The cost breakdown of the key adaptation strategies obtained from the key informants indicated that small scale farmers might not get the full benefit of investing in an expensive adaptation strategy. This is because of the low income to sustain the adaptation strategy until the full benefits are realized. Some key informants suggested that management of agricultural water is among the most effective techniques for adapting farming to climate variations and change.

*"It is possible to improve water management through various strategies including rainwater storage, boreholes, and shallow wells. However, there is need to do further investigations on the environmental implications of these techniques." Mrs. Salome Mahia (Frontline Extension Officer-Gathara Ward).*

According to the key informants' interview analysis, small scale agronomists relied on contour ridges as a technique for enhancing moisture conservation, encouraging better root penetration, and mitigating soil erosion, especially in the sloping lands of the County. In addition, the critical informant analysis findings suggested that agronomists used crop diversification, agricultural practices, and tillage techniques to maximize yields relying only on the available water supply.

*"Informant interviews acknowledge that tillage has a high likelihood of improving water infiltration rates, which reduces surface runoff associated with heavy short rains – common in most areas of the County."Mr S.M. Maina (Agricultural Officer-Kipipiri Sub County).*

Most of the key informants were concerned about the efficacy of specific adaptation strategies.

*"Implementing certain adaptation strategies takes some time, but again the climate variability extreme event becomes stronger and therefore causing substantial damage despite previous adaptation strategy" Smart Agriculture Project Consultative Forum-Nyahururu.*

At this point, the small scale farmers are faced with a choice between undertaking further costly adaptations and accepting the heightened risks. This becomes a significant challenge in evaluating the efficacy of adaptation strategies. Some key informants suggested that for an adaptation strategy to be effective, it should take up the bottom-up approach model.

*"Adaptation at the local-level mainly community-based techniques are crucial because these levels have a high likelihood that the benefits will be noticeable. Moreover, such strategies in these levels have direct implications for development since actions here are a necessity for*

*household and individual adaptation. The logic explains why such programs rank high on the government sustainable development programs". Mrs. P. M. Maina (Frontline Agricultural Extension Officer-Kiriita Ward in Ndaragwa Costituency).*

The key informants unanimously reported that the County government, in partnership with climate change smart agriculture, conducted an extensive campaign and awareness concerning the effects of variability and climate change and possible interventions to sustain crop output. This awareness resulted in applying some adaptation techniques such as crop diversification, new seed variety, and changing planting dates. The application of these adaptation strategies was associated with a steady increase in maize output between 2017 and 2019 (21,870 in 2017 to 34,289 in 2018 to 37,184 in 2019 tonnes). The key informants associated the high output of maize between 2010 and 2013 with normalized rainfall patterns in the County. During this specific period, the key informants did not necessarily associate the high output of maize with the efficacy of some adaptation strategies. The key informants also reported that the rapid changes in extreme events of climate may have lowered the output of crops even though farmers may have adapted well to this unexpected change.

From the key resource person's views and analysis, it was discovered that adaptation strategies were more effective in Irish potato crop farming compared to the maize crop. Perhaps because Irish potatoes take less time to grow and mature, i.e., three months, compared to maize which is a one-season crop, because of this reason, the trend line for variation in output of Irish potatoes was also indicating that the output of Irish potato had registered an upward trend during the previous 21 years, i.e., from 199,878 tonnes 1n 1999 to 413,160 tonnes in 2019. This was considered enough evidence that applying adaptation strategies was significant in increasing crop output in Nyandarua County.

## 7.9 Discussion of the key adaptation strategies

### 7.9.1 Crop Diversification

Crop diversification is a traditional agro-ecosystem that involves growing a variety of crops and kinds in different geographical and temporal configurations. Agroforestry is also one of the earliest agricultural practices. Farmers mimic nature's agricultural practices by incorporating trees and other permanent crops within the same household farm, along with a variety of crops, primarily vegetables and other food crops. This approach diversifies crop species, which adds to their economic relevance due to their food and nutritional worth (balanced diet) as well as a source of household income. Agricultural diversification of crops is a strategy for improving the well-being of rural households with low incomes. Its benefits include increased food security, risk reduction, job creation, and biodiversity preservation. New crop diversification opportunities are emerging, particularly for adventurous and progressive farmers.

Farmers are more vulnerable to weather fluctuations when they grow single crops like maize or Irish potatoes. Crop diversity is critical for small scale farming systems to maintain crop output stability. Crop diversification policies give a realistic option for adapting to a broader diversity of crops planted to lower the probability and risk of crop failure in this regard.

According to the findings of the study, this adaptation approach was the most commonly considered adopted adaptation strategy by slightly over a quarter of the respondents' small scale farmers (27.7 percent). In a study conducted in the Sekyedumase region of Ghana's northern region, Fosu Mensah et al., (2012) found similar results. Crop diversification was identified as an effective adaptation strategy in warmer climatic regions using a Logit analysis model of 180 farmer families. Based on the current study region, it was clear that small scale farmers had accepted the technique of cultivating various crops alternately on the same plots of land. Farmers in the drier parts of Nyandarua North had taken to growing short-season crops including beans, onions, cabbages, Irish potatoes, and fruits.

Previously, maize harvests were the main crop in certain areas of the County. Small-scale farmers in the county's cold and wet districts, such as Shamata, Wanjohi, Passenga, Engineer, and Mirangine, had embraced cultivating maize and wheat in addition to the major crop, Irish potatoes. Fruits, French beans, vegetables, green peas, and fodder crops including sunflower, oats, and beetroots were among the new crops progressively establishing themselves in Nyandarua. They have not fully adopted these new crops in all sub-counties, and farmers are also unfamiliar with the methods used to grow them, which is a restriction of these new crops. Due to these factors, maize and Irish potatoes have remained the County's backbone despite climatic problems.

The government of Nyandarua County stated that in the department of agricultural sector, focus should be given to improving the quality and quantity of agricultural production through enhanced extension programs, as well as ensuring food security through agricultural enterprise diversification (Nyandarua CIDP, 2018). The Nyandarua County government had implemented several projects to help with this, including support from agricultural institutions, greenhouse farming, farm input support, subsidized fertilizers, cut flower value chain development, value additional promotion, promotion of pyrethrum, fruit tree promotion, and Irish potato and cereals value chain development.

Secondary information from the County government indicate that between 2018 and 2020, approximately 3,000 farmers benefited from 8,100 fruit tree seedlings such as apples and avocados. 1,500 farmers received 800 bags of local Irish potato seeds and 1,000 bags of imported

Irish potato seeds. 150 farmers obtained various farm inputs for demonstration while 3,000 farmers received 2.8 million pyrethrum seedlings;

Additionally, over 100 farmers received the cut flower grading shed built at Njabini ATC as 5,000 farmers benefited from 3,510 bags of DAP subsidized fertilizer while 20 Shauri women participants profited from potato value addition equipment. Greenhouses were installed at 5 farmer groups and ten institutions. Small scale farmers have been able to adapt to the shock of climatic variable impacts by using crop diversification tactics to lessen or minimize the impact on crop production.

Over 1000 farmers in Nyandarua County have embraced diversification of high-value crops such as new Irish potato varieties, Hybrid maize varieties, grafted avocados, tissue culture bananas, French beans, and cowpeas to realize economic stability instead of relying solely on maize.

*The County chief agricultural officer Mr Muchiri Daniel said the number of farmers requesting for promotional crop seedlings is gradually rising. "Our farmers are requesting large numbers of Irish potatoes seeds, tomato tree fruits seedlings, and bananas daily, and this is impressive," he noted.*

*"The County has so far distributed 143,000 grafted avocados, 25,000 grafted tomato tree fruits seedlings and 55,500 tissue culture bananas."*

*"We are currently planting avocado on a 14-acre land. We also plant tree tomatoes as a booster to enlarge our financial basket and other cover crops that will improve our economic planning and soil fertility," said Mr Njagi-a small scale commercial farmer in Njabini.*

**Plate 7.1: A Small scale farmer in Nyandarua demonstrating crop diversification (Pepino Melon fruits and Irish potatoes on the same piece of land)**

Source: Researcher 2020

### 7.9.2 New crop varieties resistant to variations in climate

Concerning respondents' opinion that new crop varieties are more resistant to variations in climate, 50% of the respondents agreed with this opinion, while 20% disagreed. 15% were not sure that crop varieties are resistant to climate variability. These results aligned with those of a study conducted by Ngigi et al. (2016), whereby cross-tabulation analyses demonstrated that farmers who were members of community social welfare organizations had a higher likelihood of receiving group-based seed purchase help to alter crop variety and type. Crop diversification, according to Ngigi et al. (2016), entailed growing a variety of crops, including drought-resistant ones like legumes, millets, native vegetables, and exotic ones, while crop variety modification involved implementing approved and quickly maturing crop seed kinds. According to this study, small-scale farmers changed the crop variety they were growing since the new crops were drought-resistant, meaning they could withstand harsh weather conditions like disease, pest infestation, and drought while maturing quickly with little precipitation. This resistance to severe weather ensured consistent crop yields, which translated into a reliable supply of food and a means of subsistence for the household. According to an article published by Behum in 2006 about climate change and agriculture in South Africa, increasing water scarcity meant that more research was needed into the new crop varieties that were heat tolerant and less affected by water stress. The following drought-resistant hybrid maize varieties had been introduced and adopted by farmers in Nyandarua County; DH01, DH02, DH04, DH08, H532, H164D, H628, H513, H516, and H517. These new common drought-resistant varieties do well at an altitude of 1500-2800 m.a.s.l and take 70-120 days to mature with an approximate yield x90KG/acre of between 15-25 bags. These maize varieties have been attributed by small scale farmers as early and stay green, tolerant to blight and rust, suitable for Asals and dry land ecological areas, early tolerant to moisture stress, and have good husk cover and stand ability.

Modern varieties of Irish potatoes in Kenya and Nyandarua are mainly considered drought-sensitive. Asante Irish potato variety requires a high altitude of ≥2300 m.a.s.l. It has a medium maturity period of (3-4 months) with a medium to high output yield of (35-45 tons/ha). Asante variety is tolerant to Late blight disease though can still suffer the late-season infections. Desiree Irish potato variety requires a high altitude of 1800-2600 m.a.s.l. It has an early to medium maturity period of (2.5-3.5 months) with a medium to high output yield of (35-40 tons/ha). Desiree Irish potato variety is an upright medium-tall variety (about 0.7 meters in height) with dark green medium-sized leaves and strong stems. The variety produces light pink flowers which are scarcely distributed in the plant. Desiree variety is moderately tolerant of (PVY) disease.

Kenya Baraka requires a high altitude of 1600-2700 m.a.s.l. It has a medium maturity period of (3 months) with a medium to high output yield of (30-40 tons/ha). It has a long tuber dormancy of 4.5 months, making it a highly suitable drought-resistant crop. Kenya Baraka is a tall, vertical variety (about 1 meter in height) with strong stems and broad green leaves. It flowers moderately, and the flowers are white. The variety is resistant to diseases such as Late blight. Other varieties include Kenya Karibu, Kenya Mpya, Kenya Sifa, Shangi, Kenya Mavuno, Mayan Gold, Purple Gold, Sherekea, Tigoni, and Dutch Robijn.

The results of the study regarding new crop varieties were further supported by one of the main advantages of the Ricardian Empirical Model that allowed the inclusion of adaptation responses by farmers to local climate, which incorporated the challenges farmers face when introducing a new crop variety such as cost, accessibility, and benefits of the new seeds. This aspect added new knowledge to the Ricardian model by providing more optimistic insights concerning the impact of climatic variations on crop farming and adaptation than generally the doubtful results found in purely agronomic studies. However, in the literature review section of this study, the theory suffered one limitation: it failed to integrate the transition costs that a small scale farmer may incur when moving from one crop farming adaptation option to another due to climate variability. For instance the theory assumes the farmer endures the cost associated with the new crop variety introduction. The approach, however, is unable to account for the expenses incurred by switching to alternative new crops in the event that the new crop fails and a farmer plants another one. Particularly in agricultural subsectors like crop farming, where significant capital is constantly required, the costs of transition are large (Kiiru et al., 2013). The scope of the current study did not go beyond studying the transition costs of establishing a new crop variety.

About new crop variety, highland maize varieties include H626, H625, and H627. Hybrid seed varieties correspond well to different agro-ecological and climatic zones. These types maize seeds are appropriate for medium-to-high altitude regions with an elevation range of 1,500–2,100 meters above sea level, a maximum temperature of 28 degrees Celsius, and a minimum temperature of 8 degrees Celsius. Transzoia, Nyandarua, Uasin Gishu, Kericho, Nakuru, Narok, Kisii, and the highland zones of the central and eastern area are the favourable growing locations for the highland maize variety. (Kenya Seed Company, 2013). According to Schroeder et al., (2013), these varieties require precipitation ranging from 800-1,500mm.

Crop diversification policies offer one potential adaptation option by lowering the likelihood of crop failure. According to Techoro (2012), policies and initiatives aimed at fostering diversity in seed banks offer farmers a long-term chance to diversify. Moreover, crop swapping, a strategy for adaptation that involves replacing outdated hybrid plant seeds with new ones developed to withstand intense heat and drought, may boost agricultural productivity in the face of shifting moisture and temperature stress.

### 7.9.3 Adjusting planting dates/early planting

Small scale farmers in Nyandarua County had anticipated that this adaptation action to climate variability had been undertaken by several farmers. Their dependency on rain-fed crop farming made them flexible regarding when crops are planted. In the current research, 10.3% of respondents indicated that they had used adjusting planting dates as one of their coping strategies at one point or another. With the current situation of heavy rainfall concentrated in shorter periods and starting earlier than expected, some farmers had responded by adjusting the start of the planting period. In instances where the onset of rain had been delayed, farmers had reacted by also delaying the planting of crop seeds. When the onset of rain comes early, some adjustments farmers make include early planting. The interviews with small scale farmers showed that early planting done between 30th April and 2nd May 2018 contributed to yields of maize being significantly higher than of the late-planted maize crop between 14th May and 15th May 2018 as being the lowest. Late planting, therefore, remarkably reduces the establishment and yields of maize.

Farmers' other adjustments in their operation included cultivation of crops with a reduced growth period such as cabbages, potatoes, and the short growing season maize variety that takes 120 days to 140 days to mature. When long rains had extended beyond the harvesting period, farmers had been forced to harvest some crops early. Farmers often adjust planting dates in reaction to fluctuation in this scenario, especially when the first rains arrive. However, according to Deressa et al. (2009), shifting planting dates does not guarantee that crop yields will improve because most growing seasons will be shorter. Instead of planting immediately after ploughing the land, farmers await the arrival of the long rains before sowing the seeds due to the variety and uncertainty of climatic elements.

Early sowing prior to the commencement of rains has in the past resulted in seeds drying up due to unexpectedly high temperatures. Starting a maize farm early in the planting season is advantageous for market and demand reasons. The suitable time to plant is between the 15th of March and the 15th of May, though planting can begin as soon as the weather stabilizes. As a result, maize growers should not hesitate to sow through the 15th of May, anticipating maximum yield potential. Several factors, however, had a negative impact on maize yield after May 15th. First, the shorter time between plantings has a major impact on yield. Maize matures about three-four months, especially for short rain-season variants, although it might take up to 10 months or more for other types.

Irish potatoes normally take 2 to 3 months to mature after planting. When the foliage begins to turn brown, it is time to begin harvesting. When the earth is dry, harvesting is frequently done. To avoid bruises or damage to the tubers, gently dig up the potatoes from the earth during harvesting. Plant potatoes when the soil temperature four inches deep reaches around 21 degrees Celsius, or about three weeks before the first cold season. Potatoes should be sown in most parts of Kenya in February or early March. The tops can be frozen off by frost if planted too early. Irish potatoes planting dates are adjusted through three cycles: early potatoes from mid-March, earlies a few weeks later, and main crop potatoes in April for better crop yield. The current study by the researcher (2021-2023) found that adjusting planting dates in Nyandarua County, although adopted by a small percentage of the population, aligns with the findings of a survey of small-scale farmers in Ghana in a study by Fosu Mensah et al. (2012).

Crop diversification and shifting crop planting schedules were two significant tactics for adjusting to warmer temperatures. Changes in planting dates are one of a kind method favored primarily by female farmers. Early planting, according to female farmers, enables for faster seed germination since seeds sprout due to early drops of rainfall and soil moisture. Faster crop growth leads to higher yields and output as a direct result of shortened germination period. Other similar studies have highlighted conflicting results between males and females as far as this strategy are concerned. Female farmers have adopted an early planting technique to improve food security as a result of their role as home food providers, which leads to improved crop output. Male family members, on the other hand, are traditionally responsible for commencing land tiling preparations and early crop planting methods. According to this logic, female farmers will find it difficult to adopt early planting as an adaptation strategy.

### 7.9.4 Income diversification;

Research indicates that a limited number of individuals in the real world generate all their earnings from a single source, maintain all their wealth in a single asset, or employ all their assets in a single activity. As a result, we may state that diversification of the income is the norm. The process by which rural people build progressively their varied livelihood portfolios, using increasingly distinct combinations of assets and resources to enhance and support their ability to improve their living standards, meet their fundamental needs, and minimize climatic variability risk, is known as diversification.

Off-income activities also had the potential to influence the economic livelihood of the target group as among the methods of coping well with climate variability effets. This is because they largely perceived incomes from non-agricultural activities as an adaptation strategy. The current research findings indicate that 4.7% of respondents had engaged in other income-generating to supplement the low income obtained from farming. Examples of these income-generating projects that small scale farmers are engaged in include:- Engaging in small businesses like buying and selling of food products, clothes wear businesses, beauty shops, salons, barbers, hotels etc. Other income-generating activities stated by the small scale farmers were switching to livestock farming such as goat rearing and dairy cattle keeping, digging and crushing stones for sale, growing and selling fodder and pasture for livestock, and transport business such as Motorcycle (bodaboda) business. These income-generating activities could be beneficial ways for small-scale farmers to adapt and adjust to climate variability shocks (FAO, 2012b).

The current study results show that only a small section of the small holder farmers had adopted income diversification as an adaptation tool. This could result from perceiving such activities as a low return strategy. In addition, some income-generating projects required capital to start, which was not readily available. Gender differences could also have affected the uptake of off-income activities within a household. According to a study by Thorlakson & Neufeldt (2012), both primary genders in farming want to enhance and build their resilience to climate change shocks and variability through active engagement in secondary and passive income-generating opportunities to reduce poverty and reduce their reliance on agriculture. Similar research on the adaptation variables to climatic variation among cocoa farmers in southwest Nigeria was done by Oyekale et al. (2012), who discovered that men were more likely than women to diversify their crops and sources of income. Female farmers favoured diversifying their livestock portfolios, particularly producing small animals and poultry, according to the current study, to be able to increase family income and food security status. This is due to the fact that some animals, such as milk goats, do not feed a lot of grass. Despite low availability and poor quality feed during the dry season, they continue to give the family a very nutritious milk and additional revenue earnings.

## 7.10 Challenges/Limitations of adaptation to climate variability

This variable though not in the research question, was perceived to be one of the factors either directly or indirectly influenced the type of adaptation techniques taken by small-scale farming communities. Results from the participants' surveys and the deliberations carried out with extension service workers on the questionnaire sheet about the question; “Which challenges have prevented you from coping well with climate variability?” 97% of the respondents gave diverse challenges, as shown in table 7.8. However, 3% of the respondents were not able to respond to this particular question. In regard to challenges and constraints, the study indicates presence of five weighty constraints to adaptation which included: - Lack of resources/financial constraint/low income (27%), inadequate relevant skills/ limited awareness or lack of necessary information (22.3%), Fluctuations of market prices for farm produce (11%), Lack of government support/inadequate policies (8.7%) and shortage of water for irrigation (7%). Other challenges suggested by respondents included; ineffective and unsound government policies (including the distribution of irrigation equipment and fertilizers), non-availability of seeds, farmer's health status, inadequate labor to work of the farms, land shortages, and lack of information. Additionally the research also highlighted the following constraints to practical adaptation; high basic prices of food and basic supplies, communication, and public awareness. Wambua, Omoke, and Telesia (2014) found some empirical evidence that lack of adequate arable lands and other capital resources were underlying challenges to practical adaptations and, consequently, food insecurity in Kenya. These challenges as understood by the target audience greatly influenced the ineffectiveness of their adaptive capacities and were vastly overwhelming (Ochieng et al., 2016).

**Table 7.8: Challenges/limitations facing adaptation to climate variability**

| Challenge/Limitation | Frequency | Percentage | Cumulative % |
|---|---|---|---|
| Lack of resources/finances/low income | 81 | 27.0 | 27.0 |
| Limited awareness/information/relevant skills | 67 | 22.3 | 49.3 |
| Shortage of labour | 9 | 3.0 | 52.3 |
| Lack of access to credit/farm inputs | 12 | 4.0 | 56.3 |
| Lack of ready market for farm produce | 15 | 5.0 | 61.3 |
| Shortage of water for irrigation farming | 21 | 7.0 | 68.3 |
| Fluctuations of market prices for farm produce | 33 | 11.0 | 79.3 |
| Lack of adequate land | 10 | 3.3 | 82.7 |
| Lack of government support/inadequate policies | 26 | 8.7 | 91.3 |
| Other constraints/challenges | 16 | 5.3 | 96.7 |
| No response | 10 | 3.3 | 100.0 |
| Total | 300 | 100.0 | |

Source: Researcher 2021

## 7.11 Discussion on challenges /limitations of adjusting to climate variations

In Nyandarua County, majority of the issues that limited the target participant group in adapting to negative effects of climate variation were linked to poverty. Many small-scale holder farmers were unable to obtain the essential tools and technologies to adapt to crop farming effects of climate change variations due to in availability of funds. Most African farmers, according to FAO (2007), are resource-poor. They can't afford to invest in costly adaptation measures like irrigation and greenhouse technology to cushion themselves to the effects climate variability and keep their livelihoods afloat amid harsh climatic extremes like drought, which often leads to hunger.

Adapting to climate change shocks and variability is expensive (Mendelson, 2006). The absence of financial resources is a huge stumbling block. This is a common feature of small scale farming in Sub-Saharan African environment, where the majority of farmers dwelling in rural regions are poor and have limited purchasing authority. Farmers respond to climatic unpredictability by acquiring required infrastructure such as irrigation, seed types and hybrids, and weather forecasting technologies, which is highly challenging due to their inadequate resource endowment. Because fertilizers are no longer subsidized by the government in most countries, their high prices hinder small scale farmers' ability to adapt. It's also worth noting that the government's financial limits preclude itself from taking a more proactive responsibility in adapting. National and County agencies frequently lack adequate resources to fulfil their responsibilities, which forces them to prioritize alternative poverty-reduction efforts above to improve climate adaptation. Other impediments to government adaptation help include inefficient administration and a lack of accountability among some government entities.

Furthermore, small scale agriculture, the economy's backbone, has been socially and politically neglected. Richer homes in subsistence farming groups are better equipped which improves their ability to promptly mitigate climate risks; this is according to Adger et al., (2007) and Ziervogel et al., (2006). Land scarcity has been linked to increasing population pressure, which forces farmers to farm intensively on tiny pieces of land. This explains farmers' perceptions of climate variable adaptation restrictions that are consistent with Onyenechere's research (2010). Furthermore, most of the small-scale and land holders’ farmers in Africa have a traditional set-up of user rights to farmlands preferred to holding title deeds, where the custodian has the right and authority to revoke.

One of the main restrictions cited by small scale farmers preventing adaptation to climate unpredictability is lack of agricultural labour. Some opt for reducing their farmland in response to labour requirements, which limits the volume of cultivated areas. Others lack the energy to cultivate additional land areas or plots. This is owing to sicknesses and diseases that have limited the farmers' ability to work, with some of them being too weak due to old age and bad health. This limits their production to just a few hours daily. The significant migration of young and active youth to metropolitan regions in search of jobs as a means of income diversification has also contributed to the labour shortage. Some soil and water conservation adaptation measures (including composting, crop rotation, and mulching), are being hampered by labour shortages. These technologies allow farmers to better adjust to climate unpredictability while also increasing agricultural yields because they are simple and inexpensive to implement (Niggli, 2009). Other barriers to adaptation include a lack of coping skills from the target group, lack of awareness of pertinent issues, and lack of adequate information. There is a high probability of familiarity with rudimentary traditional strategies by farmers to deal with climatic unpredictability. However, the group remains largely unaware of innovative and alternative strategies because of the inaccessibility of training, education, and extension services. The same barriers contribute to high rates of possible resistance and hesitancy of transitioning from the inherited tactics to implementing new strategies (Mougou et al., 2007). Most prediction information is inadequately communicated and supplied for a limited period of time to reach small scale farmers which inhibits their capacity to grasp such opportunities. Maddison (2006) had also mentioned a paucity of information on weather and adaptation strategies as a hindrance to effective application of counter reactive measures. According to Mark et al. (2008), resource restrictions contribute to a lack of adaptive capacity, which could heighten the severity of food insecurity. Moreover, according to Benhin (2006), the degree of knowledge of farmers and accessibility to extension services are influential elements for projecting the speed at which the farmers implement climate adaptation tactics.

## 7.12 Conclusion

This chapter established that adaptation strategies applied in Nyandarua County to improve crop output amid the climate variability extremes were effective. This is because the five-year and second-year moving averages of maize and Irish potato crops, respectively, showed an increasing output trend from 2009 to 2019. The chapter presented an improved model of assessing the efficacy of adaptation strategies called the Empirical Crop Output Model. The Empirical crop output model estimates the crop output relationship based on the empirical time series of certain climatic variables using a panel data set of spatial and temporal locations. However, the model faced significant challenges in testing the hypothesis that small-scale farmers' adaptation strategies and techniques to the negative effects and shocks of climate variability had not significantly increased maize and Irish potato output. One of the most significant limitations of this model is that it lacked the empirical evidence to relate the associations amongst the two independent variables, i.e. increase in crop output and the adaptation strategies employed. A comparison of the empirical results of the two crops' output suggests that the adaptation strategies may have worked better in Irish potatoes than in maize crops. This is because the trend line in Irish potatoes was much stronger than maize output. In addition, the variation in Irish potatoes output was better illustrated in two years moving average, unlike maize output that was illustrated using five-year moving average. Because of the above limitations of the improved crop output model, a multinomial regression analytical model was adopted to test the null hypothesis of this chapter. The research relied on the multinomial logistic regression to evaluate the association between the categorical dependent variable of whether the adaptation strategy applied was effective or not, given a set of independent variables which may also have been categorical. The independent variable, in this case, was whether the adaptation strategies were very effective, effective or not effective. Based on the outcomes of the multinomial regression analysis, it was found that adopting crop diversification and applying new crop varieties as an adaptation strategy effectively increased crop output. However, adjusting planting dates and income diversification as some of the adaptations measure were less effective in improving crop yields. Perception of the efficacy of the adaptation strategy was also considered as among the determinants for adopting an adaptation strategy. In this case, it was significant in explaining the farmers' adoption of the key crop related adaptation strategies. These findings were supported by crucial informant reviews about the topic of the research study. Among the limitations of adaptations that were identified; lack of resources/finances, low income and limited awareness/information/relevant skills were the major hindrances to the application of suitable adaptation strategies.

In conclusion the associated null hypothesis was tested in two levels, i.e., the adjustment strategies by the target participants to climate variability (crop diversification and new crop variety) had not significantly increased maize, and Irish potato output was rejected. On the other hand, these strategies (adjusting planting dates and income diversification) had not significantly increased maize, and Irish potato output failed to be rejected.

# CHAPTER EIGHT

## SUMMARY OF FINDINGS, CONCLUSIONS AND RECOMMENDATIONS

### 8.1 Introduction;

The chapter presents a summary of significant findings from the study constructed from the findings of the research questions and objectives. Well, ahead, the chapter presents conclusions from the results and gives recommendations to policymakers and researchers. Finally, the researcher presents some suggested areas for further studies.

### 8.2 Summary of findings relating to the first objective (Chapter Five)

The study assessed and analysed the impact of rainfall and temperature variability on crop output for 21 years from 1999 to 2019, focusing on two food crops: maize and Irish potatoes. These crops were critical dominant in the county, with their yields and output affecting food security and livelihoods. The results showed that annual mean rainfall from 1999 to 2006 was increasing, but for 15 years, the annual rainfall varied significantly, with the highest fluctuations occurring between 2007 and 2013. Temperature changes were also significant, with the lowest annual minimum temperature recorded in 2004 and the highest annual average maximum temperature in 2000. Respondents reported that 83% of small-scale farmers had observed some changes in temperature variations over the last few years preceding the research study when it was conducted, while 70% reported that temperature had increased. The study found that rainfall variability significantly influenced the variation in maize output, with strong positive relationships between the specific two variables. However, rainfall variability had less influenced the variation in output of Irish potatoes, with a weak positive significant association between them.

Temperature variability also impacted crop output, with a weak negative significant association between minimum and maximum temperature variability and maize output. A significant rise in maximum temperature resulted in a reduction of maize output, while a slight rise in minimum temperature resulted in a slight decrease in Irish potato output.

The study analyzed the variation in maize output and Irish potato output due to climate variability using regression analysis technique. The results showed that rainfall variability resulted in 47.18% variation in maize output, while mean annual rainfall and temperature variation resulted in 8.75% and 5.9% variation respectively. The regression analysis also revealed that 53% of maize output variation and 14% of Irish potato output variation were due to both rainfall and temperature climatic factors. The study found that many small-scale farmers were conscious and alert of the changing climatic conditions, with 59.3% reporting deforestation and 27.7% believing burning fossil fuels significantly contributed to climate variability.

This trend was also observed in other African countries, where farmers believed that rainfall intensity had fallen and temperatures had increased. The study suggests that climate-related factors are contributing to the decline of crop output and food insecurity.

## 8.3 Summary of findings based on the second objective (Chapter Six)

The study assessed the influence of socio economic factors and adaptation strategies used by small-scale farmers in Nyandarua County to adapt to climate variability. The majority of the household respondents were aged above 36 years, with 63.67% being male and 36.33% female. Most respondents were married, and farming was the primary source of earnings within the many small-holder farmers in the county. In terms of adaptation strategies, 72% of respondents mentioned they could have responded to climate variability in specific ways, while 27% reported not. Crops diversification (21.21%), planting of new crop variety (20.28%), and adjusting of planting dates (13.75%) were the most popular types of adaptation tactics adopted by many small scale farmers.

The study found that respondent's age negatively influenced small scale farmers' choice of crop diversification as an adaptation technique to climate variability. The gender of the head of the household in the sampling positively influenced the adoption of crop diversification, while the level of income had a favourable and noteworthy impact on adapting to crop diversification.

Adaptation to climate variability through planting new crop varieties was positively influenced by respondent's age, while the size and proportion of land under cultivation negatively influenced the adoption of this adaptation strategy. Women were mainly affected by reduced crop yields, and the land size of crop cultivation negatively influenced farmers' choice of shifting crop planting dates. Income diversification was not a popular adaptation method among both genders, with household head education significantly positively associated with the variety of income sources. The increased number of children led to fewer family members participating in agricultural production possibly due to migration to urban areas for better employment opportunities.

## 8.4 Summary of findings based on the third objective (Chapter seven)

Chapter seven sought to evaluate the effectiveness of adaptation strategies and techniques used by small-scale farmers to adapt and adjust to shocks of climate variability in crop farming. An empirical crop output model was developed and applied to estimate the relationships between crop output and climatic variables. The results showed that adaptation strategies applied within 21 years effectively maintained and improved maize crop yield. Similarly, Irish potato output showed a significant increase in output over the same period. However, the model could not single out the most effective adaptation strategies. A more complex multinomial logistic regression statistical tool was applied to establish their relationship with farmers' perception of their effectiveness in improving crop output. The results showed that adopting crop diversification and applying new crop varieties effectively increased crop output. However, adjusting planting dates and income diversification were less effective.

## 8.5 Conclusion based on the study findings;

The study recognised that annual mean rainfall variability in Nyandarua County was highly unpredictable, affecting crop output. Small-scale farmers in the county adopted three common adaptation strategies: crop diversification, planting fast-maturing or drought-resistant crop varieties, and adjusting planting dates. These strategies were related to crop farming, which was the main economic activity among the residents. Other adaptation strategies, such as crop irrigation, income diversification, greenhouse farming technology, crop insurance, application of fertilizers and herbicides, increasing land under cultivation, and switching to livestock keeping and organic farming, were not sustainable. The size and proportion of land under cultivation, level of income, and education influenced the adoption of new crop varieties that can cope with varying climatic changes. Gender played a more significant role in coping with climate variability, with women being mainly affected by reduced crop yields. Men were considered to play a more significant role due to their decision-making and asset ownership at the community and household levels.

The research study concluded that adaptation strategies applied in Nyandarua County to improve crop output amid climate variability extremes were effective, with the high response to the effectiveness of the adaptations matching the rising trend in Irish potatoes output between 2009 and 2019.

## 8.6 Recommendations to policymakers, government and other stakeholders

Policymakers and stakeholders must develop sustainable adaptation strategies based on regional climate variability scenarios and three critical aspects: community socio-economic predispositions, government integration, and spatial ecosystem environments. Technical stakeholders like agricultural extension and frontline officers and climate smart agricultural officers, should implement these strategies considering small scale farmers' specific demographic and socio-economic susceptibilities.

Nyandarua County farmers face challenges due to reliance on rainfall for crop farming, which hinders effective adaptation to climate variability. To address this, policymakers and researchers should develop new crops and hybrids that can withstand varying climatic conditions, with early warning systems from the Kenya Department of Meteorology (KMD) and agricultural extension officers guiding farmers on proper cultivation, sowing, mulching, and harvesting schedules. Policies should support appropriate adaptation planning by monitoring climate trends and recognizing early warning systems. Continuous awareness should be provided to integrate small scale farmers' indigenous perceptions with scientific meteorological data for better planning.

Irrigation systems should be improved to supplement rain-fed agriculture, ensuring proper water management and water harvesting. Government institutions should integrate adaptations into their central policy apparatus, implementing comprehensive social protection programs and capacity building workshops for agricultural extension workers and small scale farmers. Micro-financial institutions should be established to increase income production, job creation, and enterprise growth for low-income earners.

## 8.7 Recommendations for further studies and research

The study results in Nyandarua County reveal significant challenges in addressing climate variability. The findings suggest that further research is required to understand the interrelation between climatic and agricultural factors, as well as the costs of adaptation measures for smallholder farmers. The findings also highlight the need for further research to assess the impact of other agronomic factors on crop output, thereby guiding policymakers in formulating effective and sustainable adaptation strategies.

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**APPENDIX 1. Questionnaire on climate variability and crop farming: Analysis of adaptation strategies among small scale farmers in Nyandarua County of Kenya**

**Introductory Letter for Research Questionnaire**

**Dear Participant,**

I am currently collecting data for my PhD thesis in Environmental Planning and Management at the University of Nairobi under the topic of **Climate Variability and Crop Farming; Analysis þf Adaptation Strategies among Small Scale Farmers in Nyandarua County of Kenya**

Climate variability is evident and its impact on crop farming adds significantly to the challenge of reduced crop yields. The reduced crop yield is likely to affect food security and livelihoods of small scale farmers in Nyandarua County. The information provided by you will contribute to the better understanding of the impacts of climatic variability on crop output and analyse some options for adaptation. The results will promote planned adaptation strategies and sustainable crop farming in order to enhance food security and improve livelihoods of small scale farmers. The researcher will uphold utmost integrity and ethics by ensuring that the data collected is absolutely for academic purpose and is treated with strict confidentiality.

Participation in this study is voluntary. If you have any query about this research, kindly contact the chairman & Lead Supervisor whose details are given below:

The Chairman,
Department of Geography and Environmental Studies
University of Nairobi
Email: wambua_boniface@uonbi.ac.ke

**Researcher's details**
Name: Muriithi David Ikua
Email: davidmurth2005@yahoo.com
Mobile: 0723 871 745/0736 704 768

**Guidelines: Kindly answer all the questions by ticking your correct response and/ or writing in the space(s) provided**

Questionnaire Number:____________________ Date of administration;____

Sub-County name;__________________________________________

Name of interviewee/respondent: (Optional)____________________________

Mobile:_________________ Email Addr__________________ Occupation;

**Thank you very much for answering this questionnaire.**

\

1. **General Information**

1.1 Gender:..........................................M [ ] F [ ]

1.2 Marital Status:.................................S [ ] M [ ]

1.3 Age bracket in yrs.: ........................<25 [ ] 26-35 [ ] 36-45 [ ] 46-55 [ ] Over 55 [ ]

1.4 Size of Household: ............................1-4 [ ] 5-8 [ ] 9-12 [ ] >13 [ ]

1.5 Level of education: .........................Primary [ ] Secondary [ ] College [ ] University [ ]

2. **Socio-economic characteristics of respondents**

2.1 What is your major source of income?

Farming [ ] Livestock keeping [ ] Formal employment [ ] Business [ ] Casual Labourer [ ] others [ ] Please specify:.......................................................................

...........................

2.2 Indicate your approximate total monthly income bracket in Kshs.

<10,000 [ ] 10,001-20,000 [ ] 20,001-30,000 [ ] 30,001-50,000 [ ] >50,001 [ ]

2.3 Do you have enough food for your household currently?

Yes [ ] No [ ]

2.4 How would you rate the quantity of food in your household?

Very Sufficient [ ] Sufficient [ ] Little/Inadequate/Insufficient [ ]

2.5 Who are mainly affected by reduced crop yields?

Women [ ] Men [ ]

2.6 Give the reason for your answer above.......................................................................

**3. State of knowledge on Climate variability by small scale farmers.**

3.1 Have you noticed any changes in rainfall over the last recent years?

Yes [ ] No [ ]

3.2 How has the annual rainfall amount changed?

Decreased [ ] Stayed the same (No change) [ ] increased [ ]

3.3 Have you noticed any changes in temperature over the last recent years?

Yes [ ] No [ ]

3.4 How has the annual temperature intensity changed?

Decreased [ ] Stayed the same (No change) [ ] increased [ ]

3.5 How have the following climate related factors changed in the last recent years

a) Start of onset of rainfall

Earlier than expected [ ] timely [ ] delayed [ ]

b) Length of growing periods for major crops;

Longer [ ] Stayed in the same [ ] Shorter [ ]

c) Pests and diseases

Reduced [ ] Stayed in the same [ ] increased [ ]

3.4 Use the following scale to indicate the level to which you agree with the following statements.

1-Strongly Disagree (SD) 2-Disagree (D) 3-Not Sure (U) 4-Agree (A) 5 Strongly Agree (SA)

| S/no. | Statement | SD | D | U | A | SA |
|---|---|---|---|---|---|---|
| a) | Temperature during the night have increased in the recent years | | | | | |
| b) | Temperature during the night have decreased in the recent years | | | | | |
| c) | Temperature during the night not changed in the recent years | | | | | |

3.5 What do you think are the causes of climate variability?

a) Burning fossil fuels e.g. coal, oil, gas, petrol, plastics.................................[ ]

b) Deforestation i.e. cutting down trees.....................................................[ ]

c) Don't know.......................................................................................[ ]

d) Will of God.......................................................................................[ ]

e) Others (Please specify)..........................................................................

3.6 Use the following scale to indicate the level to which you agree with the following statements.

1-Strongly Disagree (SD) 2-Disagree (D) 3-Not Sure (U) 4-Agree (A) 5 Strongly Agree (SA)

| S/no. | Statement | SD | D | U | A | SA |
|---|---|---|---|---|---|---|
| a) | Rainfall has become very unreliable and difficult to predict | | | | | |
| b) | Crops yields are higher now because of variations in climate | | | | | |
| c) | New crop varieties are more resistant to variations in climate. | | | | | |
| d) | I need to get more climates and weather information updates | | | | | |
| e) | The government is giving us information about climate variability and how to cope with it | | | | | |
| f) | More research is needed on climate variability and how to adapt it | | | | | |

**4. State of Knowledge on crop productivity and output by small scale farmers**

4.1 Which crops do you mainly cultivate (Multiple answers accepted)

Maize [ ] Wheat [ ] Beans [ ] Cabbages [ ] Irish potatoes [ ] Kales & Spinach [ ]

Green peas [ ] others [ ] (specify) ...............................................................................

4.2 What factors have influenced your decision to plant these crops? (Multiple answers accepted).

a) Water availability;.............................................................................................[ ]
b) Land ownership.................................................................................................[ ]
c) Ability to resist to climate variability;.................................................................[ ]
d) Market availability;.............................................................................................[ ]
e) Soil conditions;...................................................................................................[ ]
f) Cultural values;...................................................................................................[ ]
g) Others (specify)..................................................................................................

..........................................................................................................................

4.3 Describe the changes in crop production or output over the past 10 years?

Increased [ ] Decreased [ ] No change [ ]

4.4 If your response above is decreased, what would you consider as the major cause for the changes in crop production in your farm?

a) Climate related factors......................................................................................[ ]
b) Poor farming methods........................................................................................[ ]
c) Land degradation and soil exhaustion ................................................................[
d) Increased Pests and diseases .............................................................................[
e) High cost of inputs and poor access to credit facilities ......................................[ ]
f) Others specify;....................................................................................................

..........................................................................................................................

**5. State of knowledge on adaptation measures**

5.1 Have you responded in any way to climate variability? Yes [ ] No [ ]

5.2 If yes, which coping strategies have you applied?

a) Crops diversification/mixed cropping/ Agroforestry.............................................[ ]
b) Income diversification........................................................................................[ ]
c) Use of crop irrigation..........................................................................................[ ]
d) Crop insurance...................................................................................................[ ]
e) Drought resistant crops/change of crop variety/Fast maturing variety...................[ ]
f) Adjusting planting dates......................................................................................[ ]
g) Green house technology.....................................................................................[ ]
h) Other adaptations technique; specify;.................................................................

..........................................................................................................................

5.3 How effective have the adaptation strategies above improved your crop output?
Very effective [ ] Effective [ ] Not effective [ ]
Give the reason for your answer above..................................................................

5.4 In your opinion, which gender plays a greater role in coping with climate variability?

Men [ ] women [ ] both [ ]

Give reason for your answer above ……………………………………………………

5.5 Which challenges have prevented you from coping well to climate variability?

(Multiple responses accepted)

a) Lack of resources/financial constraint/low income……………………………[ ]
b) Limited awareness/lack of information/lack of relevant skills………………[ ]
c) Shortage of labour ……………………………………………………………[ ]
d) Lack of access to credit/farm inputs…………………………………………[ ]
e) Shortage of water for irrigation………………………………………………[ ]
f) Lack of ready market for farm produce………………………………………[ ]
g) Fluctuations of market prices for farm produce ……………………………[ ]
h) Lack of adequate land…………………………………………………………[ ]
i) Lack of government support/inadequate policies……………………………[ ]
j) Other constraints; specify:……………………………………………………

**6. Size/ownership of land and crop productivity**

6.1 How long have you lived in the study area?

1– 5yrs [ ] 6 – 10yrs [ ] 11 – 15yrs [ ] above 16yrs [ ]

6.2 Do you legally own land in the study area?

Yes [ ] NO [ ]

6.3 How big is your land under cultivation in acres?

<2 acres [ ] 2-5 acres [ ] 5-10 acres [ ] >10 acres [ ]

6.4 under what terms are you using it?

Privately Owned [ ] Communal ownership; [ ] rented; [ ] Leased; [ ] others, specify

……………………………………………………………………………………………

6.5 Indicate the type of agriculture practiced:

Rain fed [ ] Irrigation [ ] both [ ]

6.6 Indicate the type of farming practiced:

Crop Farming [ ] Pastoral Farming [ ] Nomadic pastoralism [ ] Agro forestry [ ] Mixed farming (Agro pastoral farming) [ ] others, please specify: …………………

……………………………………………………………………

6.7 Has the size of land under cultivation reduced over the last recent years?

Yes [ ] No [ ]

6.8 If yes in above what might be the reason?

Converted to livestock keeping [ ] Divided to small pieces due population increase [ ] Converted to plots for sale [ ] Abandoned due to low agricultural productivity [ ] others, please specify:……………………………………………………

**APPENDIX 2: Key Informant Interview**

Areas of residence……………………………………………………………………………………

Occupation……………………………………………………………………………………………

**PART A: ASSESSMENT OF CLIMATE VARIABILITY**

1. Has there been any observed change in climate in Nyandarua?.................................
2. Kindly describe the rainfall patterns in this area since 1999………………………
3. Kindly describe the temperature variations in this area since 1999………………
4. Is there any ongoing governemnt intervention towards climate variability?………
5. What interventions has the government made in relation to climate change?……

**PART B: CLIMATE VARIABILITY AND CROP FARMING**

6. Using a scale of 1-5, rate the following factors which have influenced crop farming in Nyandarua

| S/no. | Factor | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|
| a) | Water availability | | | | | |
| b) | Land ownership | | | | | |
| c) | Ability to resist to climate variability | | | | | |
| d) | Market availability | | | | | |
| e) | Soil conditions | | | | | |
| f) | Cultural values | | | | | |

7. In the table below rank the following factors from number 1-6 in what you would consider as the major cause for the changes in crop production in Nyandarua County.

| S/no. | Factor | Rank |
|---|---|---|
| a) | Climate related factors | |
| b) | Poor farming methods | |
| c) | Land degradation and soil exhaustion | |
| d) | Increased Pests and diseases | |
| e) | High cost of inputs and poor access to credit facilities | |
| f) | Cultural values | |

8. Maize production was highest between 2010 and 2013 in Nyandarua County. What contributed to this high output? ..........................................................................

9. Irish potatoes production has been on a steady rise from 1999 to 2019. What could be the reason? ..........................................................................................................

10. Secondary data has shown that the variation of maize output between 1999 and 2019 is very high compared to the Irish potatoes. What could be the reason? ..........................................................................................................................

**PART C: ADAPTATION MEASURES**

11. What kind of adaptation strategies have been done in Nyandarua county?...............
12. What policies are there to guide farmers of proper methods of adaptations?............
13. Classify the following methods of adaptations as either modern or traditional?.......

14. What challenges are faced by the small scale farmers in Nyandarua county in relation to climate variability adaptation?..............................................................................

15. The following table contains a number of potential adaptation measures. Please indicate by use (x) which of these are planned or autonomous.

| S/no. | Factor | Planned | Autonomous |
|---|---|---|---|
| a) | Crops diversification | | |
| b) | Income diversification | | |
| c) | change of crop variety | | |
| d) | Adjusting planting dates | | |
| e) | Greenhouse technology | | |
| f) | Crop insurance | | |

16. Please indicate in the table below what your opinion is on the availability of information and tools for different climate related aspects and adaptation measures

| Adaptation Measure | Implimented | Planned | Necessary but not planned | Not relevant/ necessary |
|---|---|---|---|---|
| Improving forecasting and information | | | | |
| Improving insurance schemes against food damage | | | | |
| Increasing water supply | | | | |
| Provision of financial aid to assist farmers in adaptation | | | | |
| Awareness raising or information campaigns | | | | |

17. Using a scale of 1-5, give weight to the following adaptation strategies as applied in Nyandarua County

| S/no. | Factor | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|
| g) | Crops diversification | | | | | |
| h) | Income diversification | | | | | |
| i) | change of crop variety | | | | | |
| j) | Adjusting planting dates | | | | | |
| k) | Greenhouse technology | | | | | |
| l) | Crop insurance | | | | | |

18. Other adaptations technique; specify.......................................................

19. Rate the following adaptation strategies in terms of their effectives: Very effective, Effective, Not effective

| S/no. | Factor | Very effective | Effective | Not effective |
|---|---|---|---|---|
| a) | Crops diversification | | | |
| b) | Income diversification | | | |
| c) | change of crop variety | | | |
| d) | Adjusting planting dates | | | |
| e) | Greenhouse technology | | | |
| f) | Crop insurance | | | |

**PART D: CONSTRAINTS OF ADAPTATIONS**

20. Using a scale of 1-5, rate the following challenges which may have prevented small scale farmers from coping well to climate variability?

| S/no. | Factor | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|---|
| a) | Lack of resources/financial constraint/low income | | | | | |
| b) | Limited awareness/lack of information/lack of relevant skills | | | | | |
| c) | Shortage of human labour | | | | | |
| d) | Lack of access to credit/expensive farm inputs | | | | | |
| e) | Shortage of water for irrigation | | | | | |
| f) | Lack of ready market for farm produce | | | | | |
| g) | Fluctuations of market prices for farm produce | | | | | |
| h) | Lack/shortage of adequate land for cultivation | | | | | |
| i) | Lack of government support/inadequate policies | | | | | |

**PART E: GENERAL INFORMATION**

21. Apart from crop farming, what other human/economic activities are affected by climate variability? ……………………………………………………………………

22. How has access to information about climate variability influenced small scale farmer's adaptation strategies? ……………………………………………………………

23. In your own opinion, how do husbands and wives in a household differ in levels of knowledge about climate variability and the coping mechanisms? ………………

24. Is there a section of Nyandarua that can be classified as semi-arid area? …………

25. If yes, name it and explain why? ……………………………………………………

26. Why did the increase in mean annual rainfall between 2017 and 2019 not significantly increase in Irish Potatoes? ………………………………………………

## APPENDIX 4 SPSS OUTPUT ANALYSIS

### REGRESSION ANALYSIS FOR RAINFALL VARIABILITY

**Model Summary**

| Model | R | R Square | Adjusted R Square | Std. Error of the Estimate |
|---|---|---|---|---|
| 1 | .342[a] | .117 | .070 | 18.47500 |

a. Predictors: (Constant), Year

**ANOVA[a]**

| Model | | Sum of Squares | Df | Mean Square | F | Sig. |
|---|---|---|---|---|---|---|
| 1 | Regression | 857.135 | 1 | 857.135 | 2.511 | .130[b] |
| | Residual | 6485.185 | 19 | 341.326 | | |
| | Total | 7342.320 | 20 | | | |

a. Dependent Variable: Annual Average Rainfall in mm

b. Predictors: (Constant), Year

**Coefficients[a]**

| Model | | Unstandardized Coefficients | | Standardized Coefficients | T | Sig. |
|---|---|---|---|---|---|---|
| | | B | Std. Error | Beta | | |
| 1 | (Constant) | -2032.725 | 1337.584 | | -1.520 | .145 |
| | Year | 1.055 | .666 | .342 | 1.585 | .130 |

a. Dependent Variable: Annual Average Rainfall in mm

### REGRESSION ANALYSIS FOR ANNUAL AVERAGE MINIMUM TEMPERATURE IN $^0C$

**Model Summary**

| Model | R | R Square | Adjusted R Square | Std. Error of the Estimate |
|---|---|---|---|---|
| 1 | .498[a] | .248 | .208 | 1.08259 |

a. Predictors: (Constant), Year

**ANOVA[a]**

| Model | | Sum of Squares | Df | Mean Square | F | Sig. |
|---|---|---|---|---|---|---|
| 1 | Regression | 7.344 | 1 | 7.344 | 6.266 | .022[b] |
| | Residual | 22.268 | 19 | 1.172 | | |
| | Total | 29.612 | 20 | | | |

a. Dependent Variable: Annual Average Minimum Temperature in 0c

b. Predictors: (Constant), Year

**Coefficients[a]**

| Model | | Unstandardized Coefficients | | Standardized Coefficients | T | Sig. |
|---|---|---|---|---|---|---|
| | | B | Std. Error | Beta | | |
| 1 | (Constant) | 204.723 | 78.379 | | 2.612 | .017 |
| | Year | -.098 | .039 | -.498 | -2.503 | .022 |

a. Dependent Variable: Annual Average Minimum Temperature in 0c

**REGRESSION ANALYSIS FOR ANNUAL AVERAGE MAXIMUM TEMPERATURE IN $^0$C**

**Model Summary**

| Model | R | R Square | Adjusted R Square | Std. Error of the Estimate |
|---|---|---|---|---|
| 1 | .371[a] | .138 | .092 | .99581 |

a. Predictors: (Constant), Year

**ANOVA[a]**

| Model | | Sum of Squares | Df | Mean Square | F | Sig. |
|---|---|---|---|---|---|---|
| 1 | Regression | 3.005 | 1 | 3.005 | 3.030 | .098[b] |
| | Residual | 18.841 | 19 | .992 | | |
| | Total | 21.846 | 20 | | | |

a. Dependent Variable: Annual Average Maximum Temperature in 0c

b. Predictors: (Constant), Year

**Coefficients[a]**

| Model | | Unstandardized Coefficients | | Standardized Coefficients | T | Sig. |
|---|---|---|---|---|---|---|
| | | B | Std. Error | Beta | | |
| 1 | (Constant) | 147.712 | 72.096 | | 2.049 | .055 |
| | Year | -.062 | .036 | -.371 | -1.741 | .098 |

a. Dependent Variable: Annual Average Maximum Temperature in 0c

## APPENDIX 5. MULTIPLE REGRESSION ANALYSIS FOR MAIZE OUTPUT AS A FUNCTION OF RAINFALL AND TEMPERATURE VARIABILITY

SUMMARY OUTPUT

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.762465 |
| R Square | 0.581353 |
| Adjusted R Square | 0.058044 |
| Standard Error | 0.792446 |
| Observations | 10 |

ANOVA

| | *Df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 5 | 3.488118 | 0.697624 | 1.110917617 | 0.472604 |
| Residual | 4 | 2.511882 | 0.627971 | | |
| Total | 9 | 6 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* | *Lower 95.0%* | *Upper 95.0%* |
|---|---|---|---|---|---|---|---|---|
| Intercept | 2.648822 | 2.262276 | 1.170866 | 0.306645341 | -3.63226 | 8.929907 | -3.63226 | 8.929907 |
| X Variable 1 | 0.341185 | 0.25843 | 1.320219 | 0.257240349 | -0.37633 | 1.058703 | -0.37633 | 1.058703 |
| X Variable 2 | 0 | 0 | 65535 | #NUM! | 0 | 0 | 0 | 0 |
| X Variable 3 | -1.14061 | 0.943259 | -1.20923 | #NUM! | -3.75952 | 1.478292 | -3.75952 | 1.478292 |
| X Variable 4 | 0.04354 | 0.274209 | 0.158785 | 0.881532563 | -0.71779 | 0.804867 | -0.71779 | 0.804867 |
| X Variable 5 | -0.23911 | 0.5 | -0.47823 | 0.65745067 | -1.62734 | 1.149109 | -1.62734 | 1.149109 |

## APPENDIX 6. MULTIPLE REGRESSION ANALYSIS FOR MAIZE OUTPUT AS A FUNCTION OF RAINFALL AND TEMPERATURE VARIABILITY

SUMMARY OUTPUT

| *Regression Statistics* | |
|---|---|
| Multiple R | 0.310973 |
| R Square | 0.096704 |
| Adjusted R Square | 0.040945 |
| Standard Error | 1.095462 |
| Observations | 87 |

ANOVA

| | *df* | *SS* | *MS* | *F* | *Significance F* |
|---|---|---|---|---|---|
| Regression | 5 | 10.40626 | 2.081252 | 1.734324 | 0.136094 |
| Residual | 81 | 97.20294 | 1.200036 | | |
| Total | 86 | 107.6092 | | | |

| | *Coefficients* | *Standard Error* | *t Stat* | *P-value* | *Lower 95%* | *Upper 95%* | *Lower 95.0%* | *Upper 95.0%* |
|---|---|---|---|---|---|---|---|---|
| Intercept | 0.945876 | 0.6936 | 1.36372 | 0.176434 | -0.43417 | 2.325923 | -0.43417 | 2.325923 |
| X Variable 1 | 0.180626 | 0.090524 | 1.995334 | 0.049368 | 0.000511 | 0.360741 | 0.000511 | 0.360741 |
| X Variable 2 | 0.196643 | 0.246247 | 0.798562 | 0.42688 | -0.29331 | 0.686597 | -0.29331 | 0.686597 |
| X Variable 3 | 0.102375 | 0.235734 | 0.434283 | 0.665237 | -0.36666 | 0.571411 | -0.36666 | 0.571411 |
| X Variable 4 | -0.05508 | 0.107235 | -0.51366 | 0.60889 | -0.26845 | 0.158283 | -0.26845 | 0.158283 |
| X Variable 5 | 0.326234 | 0.136149 | 2.396147 | 0.018873 | 0.055339 | 0.597128 | 0.055339 | 0.597128 |

## APPENDIX 7. MULTINOMIAL REGRESSION ANALYSIS FOR SOCIO-ECONOMIC FACTORS AND THE SELECTED KEY ADAPTATION STRATEGIES

**Table 1: Factors influencing small scale farmers' adaptation to crops diversification in Nyandarua County**

| Independent variables | B | Std. Error | Wald | Sig. | Exp(B) | 95% Confidence Interval for Exp(B) | |
|---|---|---|---|---|---|---|---|
| | | | | | | Lower Bound | Upper Bound |
| Intercept | -1.556 | .956 | 2.652 | .103 | | | |
| Age of the respondent | -.012 | .114 | .012 | .914 | .988 | .789 | 1.236 |
| Gender of the respondent | .155 | .274 | .319 | .572 | 1.167 | .682 | 1.997 |
| Level of education | .108 | .152 | .502 | .479 | 1.114 | .826 | 1.501 |
| Monthly income in Ksh. | .067 | .122 | .302 | .583 | 1.069 | .842 | 1.358 |
| Ownership of land under cultivation | -.185 | .111 | 2.772 | .096 | .831 | .669 | 1.033 |
| Changes in crop yields | -.118 | .275 | .184 | .668 | .889 | .519 | 1.523 |
| Effectiveness of the adaptation strategy | .378 | .142 | 7.110 | .008 | 1.460 | 1.105 | 1.927 |

**Table 2: Factors influencing small scale farmers' adaptation to new resistant crop variety in Nyandarua County**

| Independent variables | B | Std. Error | Wald | Sig. | Exp(B) | 95% Confidence Interval for Exp(B) | |
|---|---|---|---|---|---|---|---|
| | | | | | | Lower Bound | Upper Bound |
| Intercept | -2.212 | .973 | 5.165 | .023 | | | |
| Age of the respondent | .003 | .116 | .001 | .978 | 1.003 | .799 | 1.260 |
| Gender of the respondent | .038 | .281 | .019 | .892 | 1.039 | .599 | 1.801 |
| Level of education | .165 | .153 | 1.165 | .280 | 1.180 | .874 | 1.593 |
| Monthly income in Ksh. | .258 | .122 | 4.433 | .035 | 1.294 | 1.018 | 1.645 |
| Ownership of land under cultivation | -.028 | .106 | .070 | .791 | .972 | .791 | 1.196 |
| Changes in crop yields | -.273 | .273 | 1.004 | .316 | .761 | .446 | 1.299 |
| Effectiveness of the adaptation strategy | .506 | .151 | 11.200 | .001 | 1.659 | 1.233 | 2.232 |

**Table 3: Factors influencing small scale farmers' adaptation to adjusting planting dates in Nyandarua County**

| Independent variables | B | Std. Error | Wald | Sig. | Exp(B) | 95% Confidence Interval for Exp(B) | |
|---|---|---|---|---|---|---|---|
| | | | | | | Lower Bound | Upper Bound |
| Intercept | -5.482 | 1.293 | 17.973 | .000 | | | |
| Age of the respondent | .466 | .151 | 9.497 | .002 | 1.594 | 1.185 | 2.144 |
| Gender of the respondent | -.061 | .332 | .034 | .855 | .941 | .491 | 1.803 |
| Level of education | .329 | .181 | 3.297 | .069 | 1.390 | .974 | 1.983 |
| Monthly income in Ksh. | -.141 | .153 | .841 | .359 | .869 | .643 | 1.173 |
| Ownership of land under cultivation | .408 | .118 | 11.896 | .001 | 1.504 | 1.193 | 1.896 |
| Changes in crop yields | -.208 | .322 | .420 | .517 | .812 | .432 | 1.525 |
| Effectiveness of the adaptation strategy | .891 | .207 | 18.530 | .000 | 2.439 | 1.625 | 3.659 |

**Table 4: Factors influencing small scale farmers' adaptation to use of crop irrigation in Nyandarua County**

| Independent variables | B | Std. Error | Wald | Sig. | Exp(B) | 95% Confidence Interval for Exp(B) | |
|---|---|---|---|---|---|---|---|
| | | | | | | Lower Bound | Upper Bound |
| Intercept | -2.238 | 1.114 | 4.034 | .045 | | | |
| Age of the respondent | .216 | .135 | 2.581 | .108 | 1.242 | .954 | 1.617 |
| Gender of the respondent | -.266 | .323 | .679 | .410 | .766 | .407 | 1.443 |
| Level of education | .115 | .173 | .442 | .506 | 1.122 | .800 | 1.574 |
| Monthly income in Ksh. | .114 | .139 | .671 | .413 | 1.120 | .853 | 1.471 |
| Ownership of land under cultivation | .042 | .118 | .125 | .724 | 1.043 | .828 | 1.313 |
| Changes in crop yields | -.321 | .312 | 1.058 | .304 | .726 | .394 | 1.337 |
| Effectiveness of the adaptation strategy | .268 | .164 | 2.681 | .102 | 1.307 | .949 | 1.802 |

**Table 5: Factors influencing small scale farmers' adaptation to application of greenhouse farming technology in Nyandarua County**

| Independent variables | B | Std. Error | Wald | Sig. | Exp(B) | 95% Confidence Interval for Exp(B) | |
|---|---|---|---|---|---|---|---|
| | | | | | | Lower Bound | Upper Bound |
| Intercept | -3.212 | 1.502 | 4.571 | .033 | | | |
| Age of the respondent | -.153 | .184 | .698 | .404 | .858 | .598 | 1.229 |
| Gender of the respondent | -.467 | .506 | .851 | .356 | .627 | .232 | 1.691 |
| Level of education | .080 | .247 | .106 | .745 | 1.084 | .668 | 1.759 |
| Monthly income in Ksh. | .572 | .201 | 8.090 | .004 | 1.771 | 1.194 | 2.626 |
| Ownership of land under cultivation | .186 | .158 | 1.399 | .237 | 1.205 | .885 | 1.641 |
| Changes in crop yields | .104 | .433 | .057 | .811 | 1.110 | .474 | 2.595 |
| Effectiveness of the adaptation strategy | -.163 | .230 | .502 | .479 | .850 | .541 | 1.333 |

**Table 6: Factors influencing small scale farmers' adaptation to use Income diversification in Nyandarua County**

| Independent variables | B | Std. Error | Wald | Sig. | Exp(B) | 95% Confidence Interval for Exp(B) | |
|---|---|---|---|---|---|---|---|
| | | | | | | Lower Bound | Upper Bound |
| Intercept | -8.128 | 1.934 | 17.662 | .000 | | | |
| Age of the respondent | .445 | .221 | 4.068 | .044 | 1.560 | 1.013 | 2.404 |
| Gender of the respondent | -.167 | .495 | .113 | .736 | .846 | .320 | 2.235 |
| Level of education | .491 | .248 | 3.920 | .048 | 1.634 | 1.005 | 2.656 |
| Monthly income in Ksh. | .017 | .208 | .007 | .934 | 1.017 | .677 | 1.528 |
| Ownership of land under cultivation | .115 | .185 | .389 | .533 | 1.122 | .781 | 1.611 |
| Changes in crop yields | .790 | .469 | 2.832 | .092 | 2.203 | .878 | 5.526 |
| Effectiveness of the adaptation strategy | .631 | .300 | 4.415 | .036 | 1.880 | 1.043 | 3.388 |

## APPENDIX 8. MULTINOMIAL REGRESSION ANALYSIS SPSS OUTPUT TABLES

**Parameter Estimates**

| Incomediversification[a] | | B | Std. Error | Wald | df | Sig. | Exp(B) | 95% Confidence Interval for Exp(B) | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Lower Bound | Upper Bound |
| Yes | Intercept | -.860 | 1.695 | .257 | 1 | .612 | | | |
| | Gender_mainly_affected_by_reduced_crop_yields | -.222 | .400 | .307 | 1 | .580 | .801 | .366 | 1.756 |
| | responding_to_climate_variability | -1.600 | .758 | 4.454 | 1 | .035 | .202 | .046 | .892 |
| | need_to_get_more_climate_and_weather_information_updates | .064 | .238 | .073 | 1 | .787 | 1.066 | .669 | 1.699 |
| | causes_for_decreased_output_in_crop_production | -.001 | .121 | .000 | 1 | .995 | .999 | .788 | 1.267 |
| | Type_of_land_ownership_by_the_respondents | .013 | .180 | .005 | 1 | .944 | 1.013 | .712 | 1.442 |
| | Respondent's_size_of_land_under_cultivation_in_acres | -.018 | .222 | .006 | 1 | .937 | .982 | .636 | 1.518 |
| | Type_of_farming_practiced_by_the_respondent | .068 | .117 | .335 | 1 | .563 | 1.070 | .851 | 1.346 |

a. The reference category is: No.

**Parameter Estimates**

| Cropsdiversification[a] | | B | Std. Error | Wald | Df | Sig. | Exp(B) | 95% Confidence Interval for Exp(B) | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Lower Bound | Upper Bound |
| Yes | Intercept | 3.226 | 1.053 | 9.382 | 1 | .002 | | | |
| | Gender_mainly_affected_by_reduced_crop_yields | -.555 | .242 | 5.266 | 1 | .022 | .574 | .358 | .922 |
| | responding_to_climate_variability | -2.181 | .454 | 23.070 | 1 | .000 | .113 | .046 | .275 |
| | need_to_get_more_climate_and_weather_information_updates | -.143 | .136 | 1.093 | 1 | .296 | .867 | .664 | 1.133 |
| | causes_for_decreased_output_in_crop_production | -.072 | .074 | .942 | 1 | .332 | .930 | .804 | 1.076 |
| | Type_of_land_ownership_by_the_respondents | -.178 | .118 | 2.264 | 1 | .132 | .837 | .663 | 1.055 |
| | Respondent's_size_of_land_under_cultivation_in_acres | -.039 | .134 | .085 | 1 | .771 | .962 | .740 | 1.250 |
| | Type_of_farming_practiced_by_the_respondent | .122 | .071 | 2.970 | 1 | .085 | 1.129 | .983 | 1.297 |

a. The reference category is: No.

**Parameter Estimates**

| DroughtresistantNewMaturingcropvarietya | | B | Std. Error | Wald | df | Sig. | Exp(B) | 95% Confidence Interval for Exp(B) | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Lower Bound | Upper Bound |
| Yes | Intercept | 1.800 | 1.019 | 3.119 | 1 | .077 | | | |
| | Gender_mainly_affected_by_reduced_crop_yields | -.430 | .237 | 3.296 | 1 | .069 | .650 | .409 | 1.035 |
| | responding_to_climate_variability | -2.269 | .484 | 22.031 | 1 | .000 | .103 | .040 | .267 |
| | need to get more climate and weather information updates | -.043 | .136 | .102 | 1 | .750 | .958 | .734 | 1.249 |
| | causes_for_decreased_output_in_crop_production | .013 | .072 | .032 | 1 | .858 | 1.013 | .880 | 1.166 |
| | Type_of_land_ownership_by_the_respondents | .015 | .111 | .018 | 1 | .892 | 1.015 | .817 | 1.261 |
| | Respondent's_size_of_land_under_cultivation_in_acres | .222 | .132 | 2.826 | 1 | .093 | 1.248 | .964 | 1.616 |
| | Type_of_farming_practiced_by_the_respondent | .064 | .070 | .822 | 1 | .364 | 1.066 | .929 | 1.224 |

a. The reference category is: No.

| Adjustingplantingdates[a] | | B | Std. Error | Wald | Sig. | Exp(B) | 95% Confidence Interval for Exp(B) | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | Lower Bound | Upper Bound |
| Yes | Intercept | 1.219 | 1.119 | 1.186 | .276 | | | |
| | Gender_mainly_affected_by_reduced_crop_yields | -.206 | .262 | .622 | .430 | .813 | .487 | 1.359 |
| | responding_to_climate_variability | -1.780 | .474 | 14.082 | .000 | .169 | .067 | .427 |
| | need to get more climate and weather information updates | .059 | .161 | .136 | .712 | 1.061 | .774 | 1.455 |
| | causes_for_decreased_output_in_crop_production | -.091 | .086 | 1.124 | .289 | .913 | .771 | 1.080 |
| | Type_of_land_ownership_by_the_respondents | .265 | .113 | 5.485 | .019 | 1.303 | 1.044 | 1.627 |
| | Respondent's_size_of_land_under_cultivation_in_acres | -.275 | .159 | 3.010 | .083 | .759 | .556 | 1.036 |
| | Type of farming practiced by the respondent | -.123 | .085 | 2.111 | .146 | .884 | .749 | 1.044 |

**Parameter Estimates**

| Useofcropirrigation[a] | | B | Std. Error | Wald | Df | Sig. | Exp(B) | 95% Confidence Interval for Exp(B) | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Lower Bound | Upper Bound |
| Yes | Intercept | .941 | 1.250 | .567 | 1 | .451 | | | |
| | Gender_mainly_affected_by_reduced_crop_yields | .249 | .245 | 1.027 | 1 | .311 | 1.282 | .793 | 2.074 |
| | responding_to_climate_variability | -2.638 | .733 | 12.936 | 1 | .000 | .072 | .017 | .301 |
| | need_to_get_more_climate_and_weather_information_updates | -.091 | .152 | .354 | 1 | .552 | .913 | .677 | 1.231 |
| | causes for decreased output in crop production | -.043 | .083 | .266 | 1 | .606 | .958 | .815 | 1.127 |
| | Type_of_land_ownership_by_the_respondents | .023 | .126 | .035 | 1 | .852 | 1.024 | .800 | 1.310 |
| | Respondent's_size_of_land_under_cultivation_in_acres | .135 | .151 | .807 | 1 | .369 | 1.145 | .852 | 1.538 |
| | Type_of_farming_practiced_by_the_respondent | .106 | .080 | 1.737 | 1 | .188 | 1.111 | .950 | 1.300 |

a. The reference category is: No.

**Parameter Estimates**

| Greenhousetechnology[a] | | B | Std. Error | Wald | df | Sig. | Exp(B) | 95% Confidence Interval for Exp(B) | |
|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | Lower Bound | Upper Bound |
| Yes | Intercept | -1.852 | 1.486 | 1.553 | 1 | .213 | | | |
| | Gender_mainly_affected_by_reduced_crop_yields | .250 | .334 | .561 | 1 | .454 | 1.285 | .667 | 2.474 |
| | responding to climate variability | -1.435 | .680 | 4.451 | 1 | .035 | .238 | .063 | .903 |
| | need_to_get_more_climate_and_weather_information_updates | -.157 | .194 | .653 | 1 | .419 | .855 | .584 | 1.251 |
| | causes_for_decreased_output_in_crop_production | .058 | .107 | .297 | 1 | .586 | 1.060 | .860 | 1.306 |
| | Type_of_land_ownership_by_the_respondents | .181 | .154 | 1.397 | 1 | .237 | 1.199 | .887 | 1.620 |
| | Respondent's size of land under cultivation in acres | .177 | .205 | .745 | 1 | .388 | 1.193 | .799 | 1.783 |
| | Type_of_farming_practiced_by_the_respondent | .155 | .110 | 1.965 | 1 | .161 | 1.167 | .940 | 1.449 |

a. The reference category is: No.

| Cropdiversification[a] | | B | Std. Error | Wald | Sig. | Exp(B) | 95% Confidence Interval for Exp(B) | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | Lower Bound | Upper Bound |
| Yes | Intercept | -1.349 | .398 | 11.501 | .001 | | | |
| | Size_of_household_for_the_respondent | -.103 | .174 | .351 | .554 | .902 | .642 | 1.268 |
| | Respondent's size of land under cultivation in acres | .103 | .127 | .650 | .420 | 1.108 | .863 | 1.422 |
| | Type_of_farming_practiced_by_the_respondent | .153 | .066 | 5.346 | .021 | 1.166 | 1.024 | 1.328 |

| DroughtresistantNewMaturingcropvariety[a] | | B | Std. Error | Wald | Sig. | Exp(B) | 95% Confidence Interval for Exp(B) | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | Lower Bound | Upper Bound |
| Yes | Intercept | -1.635 | .402 | 16.563 | .000 | | | |
| | Size of household for the respondent | -.088 | .173 | .261 | .609 | .915 | .652 | 1.285 |
| | Respondent's size of land under cultivation in acres | .284 | .128 | 4.973 | .026 | 1.329 | 1.035 | 1.706 |
| | Type_of_farming_practiced_by_the_respondent | .098 | .067 | 2.158 | .142 | 1.103 | .968 | 1.257 |

| Adjustingplantingdates[a] | | B | Std. Error | Wald | Sig. | Exp(B) | 95% Confidence Interval for Exp(B) | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | Lower Bound | Upper Bound |
| Yes | Intercept | -.794 | .446 | 3.174 | .075 | | | |
| | Size of household for the respondent | .081 | .200 | .162 | .687 | 1.084 | .732 | 1.604 |
| | Respondent's size of land under cultivation in acres | -.288 | .155 | 3.464 | .063 | .749 | .553 | 1.015 |
| | Type_of_farming_practiced_by_the_respondent | -.091 | .082 | 1.231 | .267 | .913 | .778 | 1.072 |

| Incomediversification[a] | | B | Std. Error | Wald | Sig. | Exp(B) | 95% Confidence Interval for Exp(B) | |
|---|---|---|---|---|---|---|---|---|
| | | | | | | | Lower Bound | Upper Bound |
| Yes | Intercept | -3.358 | .711 | 22.302 | .000 | | | |
| | Size of household for the respondent | .335 | .282 | 1.414 | .234 | 1.398 | .805 | 2.429 |
| | Respondent's size of land under cultivation in acres | -.049 | .222 | .048 | .826 | .952 | .617 | 1.471 |
| | Type_of_farming_practiced_by_the_respondent | .091 | .117 | .604 | .437 | 1.095 | .871 | 1.377 |

## APPENDIX 9: PHD CALENDAR AND WORK PLAN

| YEAR | 2017 | | | | 2018 | | | | | | | | | | | | 2019 | | | | | | | | | | | | 2020 | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| ACTIVITY/TIME | S | O | N | D | J | F | M | A | M | J | J | A | S | O | N | D | J | F | M | A | M | J | J | A | S | O | N | D | J | F | M | A | M | J | J | A | S | O | N | D |
| Admission/Registration | X | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Concept paper submission | | | X | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Allocation of Supervisors | | | | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Development of proposal | | | | | X | X | X | X | X | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Literature review | | | | | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | X | | | | | | |
| Proposal Oral Presentation | | | | | | | X | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Corrections & approvals | | | | | | | | X | X | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Questionnaire development | | | | | | | X | X | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Identification of research assistants | | | | | | | | | | X | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Pre-visit & testing of questionnaires | | | | | | | | | | X | X | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Data collection – climate& data | | | | | | | | | | | | X | X | X | X | X | | | | | | | | | | | | | | | | | | | | | | | | |
| Administration of questionnaires | | | | | | | | | | | | X | X | X | X | X | | | | | | | | | | | | | | | | | | | | | | | | |
| Data entry/ | | | | | | | | | | | | | | | | | X | X | X | | | | | | | | | | | | | | | | | | | | | |
| Data analysis | | | | | | | | | | | | | | | | | | | | X | X | X | X | | | | | | | | | | | | | | | | | |
| Thesis preparation/ writing | | | | | | | | | | | | | | | | | | | | X | X | X | X | X | X | X | | | | | | | | | | | | | | |
| Manuscript for journal papers | | | | | | | | | | | | | | | | | | | | | | | | | | | X | X | X | X | | | | | | | | | | |
| Submission of 1st draft thesis | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | X | | | | | | | | |
| Publishing of journal papers | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | X | X | X | | | | |
| Thesis defence & Oral Presentation | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | | | | |
| Examination & Corrections | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | X | | |
| Thesis Printing and binding | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | |
| Thesis Submission and Clearance | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X | |
| Graduation | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | X |

## ?PENDIX 10: ADJUSTED BUDGET FOR PHD PROGRAM AND RESEARCH THESIS

| ACTIVITY | ITEM DESCRIPTION | UNITS | UNIT COST (KSH) | TOTAL COST (KSHS) |
|---|---|---|---|---|
| Tuition fee and Statutory charges | Total for Year 1, Year 2 and Year 3 | - | - | 442,100 |
| Proposal Development | Printing paper | 3 reams | 600 | 1,800 |
| | Printing services | 500 Pages | 10 | 5,000 |
| | Binding of proposal | 6 copies | 100 | 600 |
| | Internet services | | | 10,000 |
| | Travel and accommodation to the University | 80 days | 1, 000 | 80,000 |
| Field work | Field reconnaissance subsistence & fuel for 2 supervisors and student. | 2 days | 25,000 | 50,000 |
| | Data acquisition – KMD | | | 10,000 |
| | Data acquisition – Ministry of Agriculture | | | 11,000 |
| | Communication | 100 days | 250 | 25,000 |
| | Printing paper | 5 Reams | 600 | 3,000 |
| | Printing services | 1,000 pages | 10 | 10,000 |
| | Field Allowances (self, research assistants) | | | 50,000 |
| Data analysis | Data entry | 100 days | 500 | 50,000 |
| | Software for data analysis | | | 10,000 |
| | Reference books/journals | | | 35,000 |
| Journal papers | Registration and Subsistence allowance to attend conferences | | | 20,000 |
| Draft Thesis | Printing paper | 5 reams | 600 | 3,000 |
| | Printing services | 2,000 pages | 10 | 20,000 |
| | Binding services | 10 copies | 100 | 1,000 |
| Final Thesis | Printing paper | 4 reams | 600 | 3,000 |
| | Printing services | 1200 pages | 10 | 12,000 |
| | Binding services | 10 copies | 100 | 1,000 |
| | Travel and accommodation to the University | 100 days | 1, 000 | 100,000 |
| Graduation fees | | | | 4, 000 |
| TOTAL | **Fieldwork Research and Thesis Budget** | | | **511,400** |
| GRAND TOTAL | **Tuition fee and Statutory charges plus Fieldwork Research and Thesis Budget** | **Y1,Y2&Y3** | | **953,500** |

## APPENDIX 11: PHD FULL ADMISSION LETTER

**UNIVERSITY OF NAIROBI**
**GRADUATE SCHOOL**

**Telephone: +254-2-318262**
**Fax Number: +254-2-243626**
**Telegrams: "Varsity of Nairobi"**
Email: gs@uonbi.ac.ke

**P. O. Box 30197, 00100**
**NAIROBI, KENYA**

**Our Ref:** C80/52198/2017

21st June 2019

Muriithi David Ikua
C/o Chairman, Department of Geography & Environmental Studies
**FACULTY OF ARTS, CHSS**

Dear Mr. Ikua,

**FULL ADMISSION TO POSTGRADUATE STUDIES (DOCTORATE)**

Following your application for a higher degree at this University, I am pleased to inform you that the Director, Graduate School has approved your application for full registration for the degree of Doctor of Philosophy degree in **Environmental Planning and Management** at the **Department of Geography & Environmental Studies** in the **Faculty of Arts.** She has also approved **Dr. Bonface Nzuve Wambua** and **Dr. Kennedy *Japhan* Omoke** as the supervisors of your thesis entitled **"Climate Variability and Crop Farming; Analysis of Adaptation Strategies among Small Scale Farmers in Nyandarua County of Kenya."** The Guidelines on Postgraduate Supervision can be accessed on our website (www.gs.uonbi.ac.ke) while the Research Notebook is available at the University Bookstore.

The degree for which you are registered will be offered by research and thesis.

Your admission into the programme is governed by the common regulations for the degree of Doctor of Philosophy in all Faculties/Schools/Institutes. **You will be expected to carry out supervised thesis research in your chosen area of study for a minimum period of six (6) semesters, with effect from 28th May 2019, culminating in a doctoral thesis. You shall be required to file quarterly progress reports to Graduate School to confirm the progress in your research work.**

**You will also be expected to submit two (2) publications jointly published with all supervisors or acceptance letter of the two (2) publications from a peer reviewed journal from your PhD work during your oral defense.**

The fees structure for the degree of Doctor of Philosophy is as indicated below:

| A. COMPOSITE FEES (KSHS.) | Year 1 | Year 2 | Year 3 |
|---|---|---|---|
| Registration Fee | 2,000p.a. | 2,000p.a. | 2,000p.a. |
| Student Identity Card | 1,000p.a. | 1,000p.a. | 1,000p.a. |
| Tuition Fees | 108,700 | 108,700 | 108,700 |
| Supervision | 12,000 | 12,000 | 12,000 |
| Examination (Written) | 12,000 | - | - |
| Computer Fee | 5,000 p.a | 5,000p.a. | 5,000 p.a. |
| Activity Fee | 2,000p.a | 2,000p.a | 2,000 p.a |
| Medical Fee | 5,000p.a | 5,000p.a | 5,000 p.a |
| Library Fee | 6,000p.a | 6,000p.a | 6,000 p.a. |
| Caution Money (Refundable) | 5,000 | - | - |
| TOTAL | 158,700/= | 141,700/= | 141,700/= |

**B. OTHER CHARGES:**

| | | | |
|---|---|---|---|
| 1. | Extension of registration period | - | Kshs. 5,000 p.a. |
| 2. | Extension of correction period | - | Kshs. 2,000 per three months |
| 3. | Extension of revision period | - | Kshs. 3,000 per six months |
| 4. | Extension of supervision | - | Kshs. 12,000 |
| 5. | Examination of revised thesis | - | Kshs. 15,000 |

The degree for which you are registered will be offered by research and thesis and in this connection the guidelines for research money are:

| | | |
|---|---|---|
| Arts Based Research | - | Kshs. 150,000 |
| Science based Research | - | Kshs. 200,000 |
| Clinical Research | - | Kshs. 250,000 |
| Book Allowance | | Kshs. 40,000 |

**Foreign students from outside the partner states of the Northern Corridor Integration Project (Republics of Burundi, Rwanda, Uganda and South Sudan) to add 25% on all charges.**

Please note that all fees and other charges due shall be paid by **Direct Cash Deposits, EFT (Swift Code is "BARCKENX) or RTGS** transfer to **UON CESSP Collection Account No. 2032771362** at Barclays Bank of Kenya, Barclays Plaza, Nairobi, Kenya or at any Barclays Bank Branch countrywide using the Reference Number quoted above. Personal Cheques, Bankers Cheques or Institutional Cheques are **NOT acceptable**. The student account will be updated the next working day and can be accessed through the student online portal (http://smis.uonbi.ac.ke) available in the University website (www.uonbi.ac.ke). Once you have paid fees, kindly report to the Graduate School with a copy of the fees statement for registration. Thereafter, you will report to the Dean's office, **Faculty of Arts (CHSS)** for other registration formalities.

You are advised that all fees and other charges may be subject to change without prior notice.

***NB:*** ***This letter supersedes the earlier one dated 28th May, 2019.***

Yours sincerely,

**CATHERINE NJUE (MS.)**
**FOR: DIRECTOR, GRADUATE SCHOOL**

c.c. Dean, Faculty of Arts
Chairman – C/o Department of Geography & Environmental Studies
Dr. Bonface Nzuve Wambua (Supervisor) – C/o Dept. of Geography & Env. Studies
Dr. Kennedy Japhan Omoke (Supervisor) - C/o Dept. of Geography & Env. Studies.

*CN/mv*

## APPENDIX 12: APPROVAL FOR CHANGE OF COURSE NAME

**UNIVERSITY OF NAIROBI**
**OFFICE OF THE DEPUTY VICE-CHANCELLOR**
**(ACADEMIC AFFAIRS)**

**Telephone: 020-4910000**
**E-mail: pg@uonbi.ac.ke**
**REF:** C80/52198/2017

**P. O. Box 30197-00100**
**NAIROBI, KENYA**
May 20, 2022

David Ikua Muriithi
C/o Dean,
**Faculty of Arts and Social Sciences**

Dear David,

**CHANGE OF COURSE**

Please refer to your letter dated April 6, 2022 on the above subject matter.

This is to inform you that the DVC, AA has approved your request for change of course from PhD in Environmental Planning and Management Programme to **PhD in Geography and Environmental Studies Programme** in the Faculty of Arts and Social Sciences.

**This change will be effected in the system. Please note that you can now download your new admission letter in the application portal.**

Yours sincerely,

**CATHERINE NJUE (MS)**
**FOR: ACADEMIC REGISTRAR**

c.c: Dean, Faculty of Arts and Social Sciences
Chairman, Dept. of Geography, Population and Environmental Studies

CN/jg

## APPENDIX 13: FEES STATEMENT

**University of Nairobi**

A world-class university committed to scholarly excellence

Portal Home | Student Fees | Timetables | Course Registration | Results | Enquiries | Book Room | Logout

- Fee Statement
- Detailed Fee Statement
- Pay Fees Online

C80/52198/2017 DAVID IKUA MURIITHI (Nairobi Evening)

**Fees Statement**

**Academic Year :** 2017/2018 **Billing Currency :** KES

| Transaction/ Receipt Number | Date | Description | Debits DR | Credits CR | Balance | Cur.Rate |
|---|---|---|---|---|---|---|
| 2180203868 | 2017-09-22 | FEES PAYMENTS | 0.00 | 100,000.00 | -100,000.00 | KES=1 |
| 2180248607 | 2018-03-23 | FEES PAYMENTS | 0.00 | 58,700.00 | -158,700.00 | KES=1 |
| 2200023597 | 2021-03-31 | FEES PAYMENTS | 0.00 | 41,700.00 | -200,400.00 | KES=1 |
| 2200190325 | 2022-05-19 | FEES PAYMENTS | 0.00 | 1,000.00 | -201,400.00 | KES=1 |
| 2200206211 | 2022-08-18 | FEES PAYMENTS | 0.00 | 100,000.00 | -301,400.00 | KES=1 |
| 2200206212 | 2022-08-18 | FEES PAYMENTS | 0.00 | 140,700.00 | -442,100.00 | KES=1 |
| | | **Academic Year Totals :** | **0.00** | **442,100.00** | **-442,100.00** | |

**Closing Balance : -442,100.00**

About Us ·

## APPENDIX 14: UNIVERSITY RESEARCH PERMIT


**UNIVERSITY OF NAIROBI**

**DEPARTMENT OF GEOGRAPHY AND ENVIRONMENTAL STUDIES**

**Telephone: +254 2 318262**
**Extension: 28016**
**Fax: +254 2 245566**
**Email-geography@uonbi.ac.ke**

**P.O. BOX 30197-00100**
**NAIROBI**
**KENYA**


May 23, 2019

The Director,
National Commission for Science & Technology
Nairobi, Kenya.

Dear Sir/Madam,

**RESEARCH PERMIT: MURIITHI DAVID IKUA**

This is to confirm that the above named is a registered student (Registration Number – C80/52198/2017) at the Department of Geography and Environmental Studies, University of Nairobi pursuing a Ph.D. in Environmental Planning and Management (EPM).

Mr. Muriithi is currently undertaking research on a topic titled: **Climate Variability and Crop Farming: Analysis of Adaptation Strategies Among Small Scale Farmers in Nyandurua County of Kenya..**

Any assistance accorded to him will be highly appreciated.

CHAIRMAN
Department Of Geography
and Environmental Studies
UNIVERSITY OF NAIROBI

**Dr. Boniface Wambua**
**Chairman, Department of Geography & Environmental Studies**

## APPENDIX 15: NACOSTI RESEARCH PERMIT

REPUBLIC OF KENYA

NATIONAL COMMISSION FOR SCIENCE, TECHNOLOGY & INNOVATION

Ref No: 559697

Date of Issue: 21/August/2019

**RESEARCH LICENSE**

**This is to Certify that Mr.. MURIITHI IKUA of University of Nairobi, has been licensed to conduct research in Kiambu, Laikipia, Muranga, Nairobi, Nakuru, Nyandarua, Nyeri on the topic: CLIMATE VARIABILITY AND CROP FARMING; ANALYSIS OF ADAPTATION STRATEGIES AMONG SMALL SCALE FARMERS IN NYANDARUA COUNTY OF KENYA for the period ending : 21/August/2020.**

License No: NACOSTI/P/19/793

559697

Applicant Identification Number

Director General
NATIONAL COMMISSION FOR SCIENCE, TECHNOLOGY & INNOVATION

Verification QR Code

NOTE: This is a computer generated License. To verify the authenticity of this document, Scan the QR Code using QR scanner application.

## APPENDIX 16: GRADUATE STUDENTS PROGRESS REPORT 2020

UNIVERSITY OF NAIROBI
GRADUATE SCHOOL

RECEIVED 21 JAN 2020

**GRADUATE STUDENTS PROGRESS REPORT**

The following is a format for postgraduate quarterly progress reports for graduate students undertaking the programme by thesis. A completed report should be sent to the Director, GS through Chairman and Dean/Director with a copy to the Principal of the respective College.

Name of Student DAVID I. MURIITHI Reg. No. C80/52198/2017

Programme PhD - ENVIRONMENTAL PLANNING AND MANAGEMENT

Department GEOGRAPHY AN ENVIRONMENTAL STUDIES

Faculty/School/Institute ARTS

Date of Registration 28/05/2019

Proposed date of completion 31/12/2020

Title of Project/Thesis Climate Variability and Crop Farming: Analysis of Adaptation Strategies among Small Scale farmers in Nyandarua County of Kenya.

Where project is being conducted Nyandarua County

Supervisors:

| | Name | Department |
|---|---|---|
| 1. | Dr. Boniface Wambugu | DoGES |
| 2. | Dr. Kennedy Omoke | DoGES |
| 3. | | |

1) **Short introduction and objectives**

- Student to provide a brief statement and the objectives of the study.

General Objective

- To assess, evaluate and document the adaptation strategies established by small scale farmers in response to the impact of climate variability on crop farming in Nyandarua County.

Specific Objectives

1) To assess the climate variability of mean annual rainfall and temperature and its impact on crop farming
2) To evaluate strategies used by small scale farmers to adapt to effect of climate variability on crop farming.
3) To assess the influence of demographic and socio economic factors that influence adaptation strategies in crop farming

2) **Accomplished work for specified period: From ( ) To ( )**

- State your actual progress in comparison to the planned progress. (Gantt chart)

- Primary Data collection completed on 15/07/2020

3) **Remaining work**

- State clearly what remains to be done for the stated period if any. If not, how and when it will be accomplished.

- Secondary Data Collection, Data Analysis and Thesis Draft writing

- State what assistance is required.

4) **Any other comments** Have Received Remarkable Support from Supervisors

Student Name David I. Muriithi Signature [signature] Date 20/01/2020

**Comments by supervisors**

1) Name DR B. Wambugu Department Geography & Env. Stud.
Comments Good progress made
Signature [signature] Date 22/1/2020

2) Name Dr Omolle Department Geography & Environmental St.
Comments Good Progress noted
Signature [signature] Date 20/01/2020

**Comments by Chairman**

Make statement on progress of the student and proposed improvement.

Name DR B. Wambugu Signature [signature] Date 21/1/2020

**Comments by Dean/Director**

Make statement on progress of the student and proposed improvement.
Good Progress noted

Name E. W. Wahome Signature [signature] Date 21.1.2020

FACULTY OF ARTS UNIVERSITY OF NAIROBI 21 JAN 2020 P.O. Box 30197, NAIROBI

## APPENDIX 17: GRADUATE STUDENTS PROGRESS REPORT 2021

UNIVERSITY OF NAIROBI
GRADUATE SCHOOL

RECEIVED 13 JAN 2021

GRADUATE STUDENTS PROGRESS REPORT

The following is a format for postgraduate quarterly progress reports for graduate students undertaking the programme by thesis. A completed report should be sent to the Director, GS through Chairman and Dean/Director with a copy to the Principal of the respective College.

Name of Student DAVID IKUA MURIITHI Reg. No. C80/52198/2017

Programme PhD IN ENVIRONMENTAL PLANNING & MANAGEMENT

Department GEOGRAPHY AND ENVIRONMENTAL STUDIES

Faculty/School/Institute ARTS

Date of Registration 28/05/2019

Proposed date of completion DECEMBER 2021

Title of Project/Thesis Climate Variability and Crop Farming: Analysis of Adaptation Strategies Among Small Scale farmers in Nyandarua County of Kenya

Where project is being conducted Nyandarua County - Kenya.

Supervisors:

| | Name | Department |
|---|---|---|
| 1. | Dr. Boniface Wambua | DOGES |
| 2. | Dr. Kennedy Obiero | DOGES |
| 3. | | |

1) **Short introduction and objectives**

- Student to provide a brief statement and the objectives of the study.

- The general objective of the research is to evaluate the adaptation strategies established by small scale farmers in response to the impact of climate variability on crop farming in Nyandarua County
- The study is guided by three specific objectives

2) **Accomplished work for specified period: From ( ) To ( )** 1st Jan 2020 – 31st Dec 2020

- State your actual progress in comparison to the planned progress. (Gantt chart)

1st objective (Chapter 4) draft writing complete.

3) **Remaining work**

- State clearly what remains to be done for the stated period if any. If not, how and when it will be accomplished.

2nd and 3rd objective draft writing.

- State what assistance is required. Data analysis and organization of the chapter 5 & 6 (2nd & 3rd objective)

4) **Any other comments** – We have interacted with my supervisors through online platform due to Covid-19. Remarkable support.

Student Name D. I. Muriithi Signature [signature] Date 13/01/2021

**Comments by supervisors**

1) Name [signature] Dr. Boniface Wambua Department Geography & Env. Stud.
Comments The candidate is progressing well with draft writing. Currently doing analysis of 3rd objective
Signature [signature] Date 13/1/2021

2) Name Dr. Obiero Department Geography & Env. Stud.
Comments Candidate is making good progress.
Signature [signature] Date 13/1/2021

**Comments by Chairman**

Make statement on progress of the student and proposed improvement.
Name Dr. B. Wambua Signature [signature] Date 13/1/2021

**Comments by Dean/Director**

Make statement on progress of the student and proposed improvement.
Good progress
Name E. W. Wahome Signature [signature] Date 14.1.21

## APPENDIX 18: GRADUATE STUDENTS PROGRESS REPORT 2022



**UNIVERSITY OF NAIROBI**
**GRADUATE SCHOOL**

**GRADUATE STUDENTS PROGRESS REPORT**

The following is a format for postgraduate quarterly progress reports for graduate students undertaking the programme by thesis. A completed report should be sent to the Director, GS through Chairman and Dean/Director with a copy to the Principal of the respective College.

Name of Student Muriithi David Ikua Reg. No. C80/52198/2017

Programme PhD IN ENVIRONMENTAL PLANNING AND MANAGEMENT

Department GEOGRAPHY POPULATION AND ENVIRONMENTAL STUDIES

Faculty/School/Institute ARTS AND SOCIAL SCIENCES

Date of Registration 1ST SEP 2017

Proposed date of completion 21ST DEC 2022

Title of Project/Thesis CLIMATE VARIABILITY AND CROP FARMING; ANALYSIS OF ADAPTATION STRATEGIES AMONG SMALLSCALE FARMERS IN NYANDARUA COUNTY OF KENYA.

Where project is being conducted NYANDARUA COUNTY

Supervisors: Name / Department

1. DR. BONIFACE WAMBUA - GEOGRAPHY, POP. & ENV. STUDIES
2. DR. KENNEDY MUOKE - ||
3.

**1) Short introduction and objectives**

- Student to provide a brief statement and the objectives of the study.

- The general objective of the research is to assess, evaluate and document the adaptation strategies established by small scale farmers in response to the impact of climate variability on crop farming in Nyandarua County.

**2) Accomplished work for specified period: From ( ) To ( )**

Fieldwork complete & data analysis complete.

- State your actual progress in comparison to the planned progress. (Gantt chart) - Progress is behind the planned schedule - draft thesis already written.

**3) Remaining work**

- State clearly what remains to be done for the stated period if any. If not, how and when it will be accomplished. - Waiting for my supervisors to have a final reading of my draft thesis.
- State what assistance is required. Lecturers (Supervisors) to accept the draft and forward to the examiners.

**4) Any other comments**

I have received a lot of support from my supervisors

Student Name David I. Muriithi Signature [signature] Date 6/4/2022

**Comments by supervisors**

1) Name DR B. Wambua Department Geography, population and Env. Studies

Comments The student is progressing well with final editing of the thesis

Signature [signature] Date 6/4/2022

2) Name ______ Department ______

Comments ______

Signature ______ Date ______

**Comments by Chairman** Good progress from the candidate & supervisors

Make statement on progress of the student and proposed improvement.

Name Dr. B. Wambua Signature [signature] Date 6/4/2022



**Comments by Dean/Director**

The student's thesis is complete but with supervisors for final check before presentation to Dean.

Make statement on progress of the student and proposed improvement.

Name Prof. Jack Odhiambo Signature [signature] Date 7/5/22

**APPENDIX 19: FIELDWORK AUTHORIZATION LETTER BY THE COUNTY GOVERNMENT**

REPUBLIC OF KENYA

COUNTY GOVERNMENT OF NYANDARUA

OFFICE OF THE GOVERNOR

COUNTY SECRETARY AND HEAD OF PUBLIC SERVICE

Telephone: 0202660859
Fax: 02026660859
Website: www.nyandarua.go.ke
Email: cs@nyandarua.go.ke

P.O. Box 701-20303
OlKalou
Kenya

*When replying please quote:*
Ref; NYA/CNT.GOVT/ADM/1/23/1

29th November, 2019

**THE DIRECTOR,**
**NACOSTI,**
**P.O BOX 30623-00100,**
**NAIROBI .**

**DAVID MURIITHI IKUA**

This is to confirm that the above named person, a student from University of Nairobi has reported to the Nyandarua County and authorized to a take Research on **"Climate Variability and Crop Farming",** Analysis of Adaptation Strategies among small scale farmers in Nyandarua County.

Please accord him necessary assistance.

COUNTY SECRETARY
THE COUNTY GOVERNMENT OF
NYANDARUA

**HIRAM M. KAHIRO**
**COUNTY SECRETARY AND HEAD OF PUBLIC SERVICE**

Copy to :

Chief Officer- Agriculture, Livestock and Fisheries

**APPENDIX 20: APPOINTMENT LETTER FOR RESEARCH ASSISTANT**

David Ikua Muriithi,
University Of Nairobi,
Po Box 30197-00100,
Nairobi, Kenya.
C80/52198/2017.
Mobile No: 0723871745/0736704768
Email address: david.ikua@students.uonbi.ac.ke

26th August 2019

# TO WHOM IT MAY CONCERN

**RE: APPOINTMENT OF RESEARCH ASSISTANT**

This is to confirm that I **David Ikua Muriithi**, a Postgraduate student of the University of Nairobi, has appointed and engaged **MR. JOHN WAMUTI MURIITHI, ID NO: 22109331 & MOBILE PHONE NO: 0708252749** to be my research assistant in collecting data in Nyandarua County (Small scale farmers and agricultural officers) on the topic: **CLIMATE VARIABILITY AND CROP FARMING; ANALYSIS OF ADAPTATION STRATEGIES AMONG SMALL SCALE FARMERS IN NYANDARUA COUNTY OF KENYA** for the period ending: 21/August/2020.

This research has been authorized by the University of Nairobi and licensed by the National Commission for science and technology. **License No: NACOSTI/P/19/793.**

Kindly accord him the necessary support

Yours faithfully,

David Ikua Muriithi

**PhD Student**

**APPENDIX 21: CERTIFICATE OF PARTICIPATION FOR CONFERENCE AND PAPER PRESENTATION**

HORTI GREEN

CERTIFICATE OF PARTICIPATION

*This is hereby granted to*

*David Muriithi*

*For participating in the E-conference on Sustainable Consumption & Production Practices in the Food Value Chain October 05-07, 2020*

DR. GEORGE ABONG'
University of Nairobi

THE HORTIGREEN CONSORTIUM
Sustalde, UoN, KEBS, CIN

FUNDACION SUSTALDE · KEBS · cin · switchafrica GREEN · SWITCH Africa Green is funded by the European Union

**APPENDIX 22: FIRST ARTICLE PUBLICATION AUGUST 2020**

*Asian Journal of Agriculture and Food Sciences (ISSN: 2321 – 1571) Volume 8 – Issue 4, August 2020*

*Asian Online Journals (www.ajouronline.com) 85*

# Characterization of Small Scale Farmers' Low Levels of Adoption to Crop Insurance as an Adaptation Strategy to Climate Variability in Nyandarua County of Kenya

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Kiriaini, Kenya
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**ABSTRACT**----- *Kenya is one of the many countries in Sub Saharan Africa affected by climate variability and its related hazards due to changes in temperature and variations in rainfall in most parts of the country. The present study has been undertaken to assess the adaptation strategies applied by the small scale farmers in response to climate variability in Nyandarua County. The study has been conducted in central region of Kenya which is relatively humid and good for agricultural production. A total sample size of 300 respondents from five sub counties was used to collect the primary data through the random sampling technique. Descriptive Likert analysis and Inferential binary logit regression was used to assess the factors affecting the willingness to adopt crop insurance to mitigate the risks of variability of climate on crop farming. The results of the study indicate that adoption of crop insurance scored very low in relation to other adaptation strategies. The logit regression model on the other hand revealed that age and marital status was positively significant with willingness to adopt crop insurance while the marginal effects of levels of income and monthly income implied that the likelihood of willingness to adapt crop insurance increased by 1.32 times and 13.3 percent respectively. Based on the study findings, if small scale farmers are well supported to adopt crop insurance, then this adaptation strategy can be among the most effective strategies in Kenya. However, due to low adaptive capacity, more awareness needs to be created on the importance and procedures of obtaining the specific agricultural insurance covers. The study concludes that modern adaptation approaches are important in presence of formal crop insurance policies especially in the rural areas of Kenya.*

**Keywords**---- Climate variability; adaptation strategies; crop insurance; binary logit model

**APPENDIX 23: SECOND ARTICLE PUBLICATION MAY 2021**

EISSN: 2707-0425

*East African Journal of Science, Technology and Innovation, Vol. 2 (Special issue): May 2021*


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**Constraints and Opportunities for Greenhouse Farming Technology as an Adaptation Strategy to Climate Variability by Smallholder Farmers of Nyandarua County of Kenya**

[1]* MURIITHI D I., [1]WAMBUA B N., [1]OMOKE K J

[1]Department of Geography & Environmental Studies, University of Nairobi, P.O. Box 30197, Nairobi- Kenya.

*1Corresponding author: davidikua44@gmail.com

**Abstract**
Nyandarua County of Kenya has been for a long time, manifested itself as one of the major food baskets in the country. This is because of its high and sustainable output in crop farming i.e., maize, Irish potatoes, wheat, and other horticultural crops like vegetables and fruits. However, this scenario has recently changed because the usual high crop output has not been forthcoming due to recent changes in climatic patterns where rainfall has become very unreliable and temperatures very extreme. In an attempt to adapt to this climate variability and its associated negative impacts on crop farming, smallholder farmers have tried to apply the greenhouse farming technology for them to be able to maintain and or improve the various crop output amid the climatic changes. The study aims to examine and assess the socio-economic determinants and constraints associated with this attempt of adaptation strategy. Using the primary data of 300 respondents (Smallholder farmers) in the County, the study adopted a logistic regression analysis model to associate the demographic, socio-economic, and constraints encountered by the smallholder farmers with the adoption of the greenhouse farming technology. The study results indicate that this adaptation strategy was reported by 25 out the 300 smallholder farmers (5.83%). The study results further suggest that financial constraints (27%) and lack of information (22.3%) are the major constraints preventing smallholder farmers from effectively adopting this adaptation strategy. However, the probability results of logistic regression analysis (68%) indicate that if properly adopted, the method can provide a solution to the currently reduced food shortages and increase food security among the smallholder farmers of Nyandarua County of Kenya.

**Keywords:** *Adaptation strategies; climate variability; greenhouse farming technology; logistic regression model.*

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**APPENDIX 24: ACCEPTANCE LETTER FOR THIRD ARTICLE PUBLICATION**

International Journal of Agriculture, Environment and Bioresearch

www.ijaeb.org

ISSN: 2456-8643

IJAEB

## ACCEPTANCE LETTER

Dear Author's

**Muriithi D.I., Wambua B.N. and Omoke K.J.**

Congratulations! The Editorial Team of International Journal of Agriculture, Environment and Bioresearch "**ASSESSMENT OF RAINFALL VARIABILITY AND MAIZE CROP FARMING IN NYANDARUA COUNTY, KENYA**" has been accepted for the publication.

Please note, as per the Instructions for authors, all manuscripts must be accompanied by a signed copyright form to progress through to the final stages of production. You are requested to send the copyright transfer agreement form after receiving this mail so that we can proceed with the publication. For your convenience the copyright form is attached herewith. Please print and sign the attached copyright form and send the scanned copy to the email address: editor@ijaeb.org

You are requested to complete the payment formalities so that your article can be accommodated in latest issue of journal. We recommend electronic fund transfer to avoid postal delay in receiving the article fees at the editorial office. Once done you are requested to send an acknowledgement email along with payment receipt as an attachment.

With Regards

gvaishnav

Editor-in-Chief

International Journal of Agriculture, Environment and Bioresearch

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**APPENDIX 25: THIRD ARTICLE PUBLICATION JANUARY 2023**

International Journal of Agriculture, Environment and Bioresearch

Vol. 08, No. 01; 2023

ISSN: 2456-8643

# ASSESSMENT OF RAINFALL VARIABILITY AND MAIZE CROP FARMING IN NYANDARUA COUNTY, KENYA

[1]Muriithi D.I., [2]Wambua B.N., and [2]Omoke K.J.

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https://doi.org/10.35410/IJAEB.2023.5801

## ABSTRACT

Crop farming is crucial to the livelihoods of communities living in the rural areas of Kenya. The sector largely depends on climatic variables such as rainfall for optimum crop output. This article presents the analysis, interpretation and discussion of the research findings based on the objective of assessing the climate variability of mean annual rainfall and its impact on crop farming (maize output) in Nyandarua County. To achieve this objective, the researcher sought to analyse rainfall amount and fluctuations in Nyandarua County for 21 years and correlate the variable with crop output (maize) over the same period. The variability of rainfall and maize output was analysed using descriptive statistics of mean, standard deviation and coefficient of variance. Simple line trends and scatter graphs were used to show this variation. The inferential statistics of regression and correlation analysis were used to establish the relationship between the rainfall factor and the selected crop output. The null hypothesis associated to this objective was tested using results of the correlation and regression analysis. Evidence of the study indicated that the annual average rainfall had increased from 1999 to 2006. However, the last fifteen years preceding the study, the mean annual rainfall had significantly fluctuated between the peaks of 117 mm and off peaks of 67 mm. The utmost variation in the rainfall amount was experienced between the years 2013 and 2007. Referring to the 21-year period of annual crop output records, the output of maize greatly fluctuated between 2019 and 1999 with an average tonnes of 29,145.76. Rainfall variability was concluded to have greatly influenced the changes in maize output (r=0.688). The regression line for rainfall variability and maize output produced a slope that was described by the equation y=463x - 11100 + ἑ. The regression value (R2 = 0.47189 showed that 47.19% of the fluctuation in maize output was as a result of the disparity in rainfall amount and distribution. In conclusion, results of the study implied that rainfall amount and distribution was highly erratic and unpredictable. Therefore this scenario exhibited much uncertainty to the small scale farmers in the region. For better planning of the effect of climate variability, the study recommended that policymakers and other relevant stakeholders should come up with awareness programs through the provision of useful information that assimilate the small holder farmer indigenous knowledge and perception and its effects on their livelihoods with the accurate meteorological scientific data.

**Keywords:** Rainfall variability; logistic regression model; crop variability; adaptation strategies;

**APPENDIX 26: THIRD ARTICLE PUBLICATION CERTIFICATE**

## International Journal of Agriculture, Environment and Bioresearch

ISSN: 2456-8643

http://ijaeb.org/

**Certificate of Publication**

This is to certify the paper titled "**ASSESSMENT OF RAINFALL VARIABILITY AND MAIZE CROP FARMING IN NYANDARUA COUNTY, KENYA"** submitted by Author's "**Muriithi D.I., Wambua B.N., and Omoke K.J."** has been published for **Jan-Feb 2023** Volume 8, Issue 1, online publication under ISSN 2456-8643.

With Regards

gvaishnav

Editor-In-Chief
International Journal of Agriculture, Environment and Bioresearch

http://ijaeb.org/

**APPENDIX 27: INTERNATIONAL GRADUATE SCHOOL CERTIFICATE OF PHD STUDENT TRAINING**

**international**
**graduate school**
north-south

on global change, innovation, and sustainable development

# Training Certificate

This is to certify that

David Muriithi

has successfully participated in the Summer School of the IGS North-South offered by the Universities of Basel, Bern, Lausanne and Zurich on:

**Common pool resources in a globalised world**

from 3 to 13 July 2023 in Nanyuki, Kenya

The participants learned theoretical foundations and methods of integrative development research and interventions. Furthermore, they gained hands-on experiences during fieldwork.

The training included the following modules:

- **Conceptual seminars**
- **Methodological seminars**
- **Field studies**
- **Scientific writing course**

**Prof. Dr. Laurent Goetschel**
President of the IGS North-South

**Dr. Boniface Kiteme**
Director Centre for Training and Integrated Research in ASAL Development (CETRAD)

Nanyuki, 12 July 2023

**ECTS** – (European Credit Transfer System) 5

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## UNIVERSITY OF NAIROBI

### Declaration of Originality Form

This form must be completed and signed for all works submitted to the University for Examination

**PART 1: PARTICULARS OF THE CANDIDATE**

Name of Student: **Muriithi David Ikua**

Registration No: **C80/52198/2017**

PROGRAMME: **Doctor of Philosophy Degree**

SPECIALIZATION: **Geography and Environmental Studies**

DEPARTMENT: **Department of Geography, Population and Environmental Studies**

FACULTY: **Faculty of Arts and Social Sciences**

**PART II: PARTICULARS OF THESIS/DISSERTATION/PROJECT PAPER**

TITLE: **Analysis of the effect of climate variability and socio-economic factors on adaptation strategies among small scale farmers. A case study of Nyandarua County, Kenya**

**PART VI: CANDIDATE'S DECLARATION**

1. I understand what plagiarism is and I am aware of the University's policy in this regard;
2. I declare that this **Thesis** is my original work and has not been submitted elsewhere for examination, award of a degree or publication. Where other people's work or my own work has been used, this has properly been acknowledged and referenced in accordance with the University of Nairobi's requirements.
3. I have not sought or used the services of any professional agencies to produce this work.
4. I have not allowed, and shall not allow anyone to copy my work with the intention of passing it off as his/her own work.
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I **Muriithi David Ikua** Reg. No.: **C80/52198/2017**

Registered on **21st June 2019** hereby confirm that the thesis I intend to submit contains my original work and has not been submitted for examination elsewhere or before.

Sign: ______________ Date: **1st November 2023**

*Declaration of Originality Form* *August 2021*