IMPACTS OF CLIMATE CHANGE AND VARIABILITY ON SMALL-SCALE IRISH POTATO PRODUCTION IN NDARAGWA AGRO-ECOLOGICAL ZONE, NYANDARUA COUNTY, KENYA

BY

BEATRICE WANGUI NDEGWA

A THESIS SUBMITTED TO THE SCHOOL OF ARTS AND SOCIAL SCIENCES, DEPARTMENT OF GEOGRAPHY IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE AWARD OF THE DEGREE OF DOCTOR OF PHILOSOPHY IN GEOGRAPHY

MOI UNIVERSITY

2021

DECLARATION

Declaration by Candidate

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

Signature…………………………….. Date…………………………..

Beatrice Wangui Ndegwa

SASS/D.PHIL/GEO/01/2014

Declaration by the Supervisors

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

Signature…………………………….. Date…………………………..

Prof. Paul Omondi

Department of Geography

Moi University

Signature…………………………….. Date…………………………..

Dr. Fredrick Okaka

Department of Geography

Moi University

DEDICATION

This work is dedicated to my late father Mr. Samuel Ndegwa for the sacrifice and encourangement he gave throughout my studies, to my dear mum Mrs. Grace Ndegwa for her love for education and her support, to my dear husband Kihuga Ndung'u for the love and patience he showed throughout and to my loving children Shanice Nyambura and Ashermoses Ndung'u.

ACKNOWLEDGEMENT

I owe immense gratitude to my supervisors Prof. Paul Omondi and Dr. Fredrick Okaka both of Department of Geography and environmental studies, Moi University, who offered sage advice, insightful criticisms, patience and encouragement that contributed immensely to the quality of this work.

I would also like to acknowledge the support and assistance given to me by the District Agricultural Office in Nyahururu, the Kenya Meteorological Station headquarters and all the respondents that willingly filled the questionnaires and participated in interviews. Without their availed data the work could not have been a success.

Am highly indebted to my family, my parents Mr. and Mrs Samwel Ndegwa for the encouragement and prayers they gave me throughout the study; to my Husband Kihuga Ndung’u, who tirelessly supported me; Daughter Shanice Nyambura and son Ashermoses Ndung’u for their patience, love and perseverance during many times they accompanied me as I travel to the field for my data collection.

My special thanks go out to my research assistants especially Gerald Kamotho who coordinated other four research assistants whom we worked with tirelessly to collect necessary data for this project. I also highly acknowledge Dr. Janet Korir who accompanied me in the field during the training of the research assistants.

I would also acknowledge Grace Wamboi and Simon Murimi (Agricultural extension Officers, Ndaragwa and Kiriita wards respectively) for their commitment in directing me to some of the Key Informants who had more experience in Irish potato growing.

Lastly but not least, I would not forget colleagues at the Department of Geography and Environmental studies, Moi University, Particularly Jack-Willis Okumu Abok who willingly took up my work responsibility during my absence when I went for data collection. Above all, I extend my special gratitude to the almighty God for His love, Favors, protection and provision throught out my PhD Programme.

ABSTRACT

There is growing evidence of climate change and variability with indicator such as floods, extremely high temperatures, frosts, famine and low temperature. These extreme events of Climate change and variability have proved to pose serious risks that have adverse consequences on production of Irish potato. Despite such risks, there have been few studies on climate change effect on Irish potatoes production and particularly from the farmer's perspective especially in semi-arid zones of Kenya. This study therefore was designed to establish the impacts of climate change and variability on small scale Irish potato production in Ndaragwa. The specific objectives were: to analyze the nature of climate change and variability in Ndaragwa agro-ecological zone; to determine the small scale Irish potato farmer's awareness of climate change and variability in Ndaragwa; to assess small scale Irish potato farmer's perception of the impacts of climate change and Variability on Irish potato production; to establish the relationship between Irish potato production and climate elements in Ndaragwa and to establish the practices and technologies related to climate change adaptation on Irish potato production among the communities in Ndaragwa . The study adopted a cross-sectional survey of respondents from the four wards of Ndaragwa constituency. The sample size of 398 households was selected using Krejcie and Morgan's table of determination. Random and systematic sampling was used to obtain the household respondents who completed the semistructured questionnaire. The questionnaire was supplemented with 5 Focus Group Discussions (FGDs) and 10 Key Informant Interviews (KIIs). The study used resilience theory in synthesizing a conceptual framework and the analysis was done using Statistical Package for Social Sciences (SPSS) Computer software version 23. The study established that climate change and variability is indeed taking place in Ndaragwa with cases of increased temperatures and erratic rainfall being observed from the analysis. The majority (95.5%) of the respondents are aware that climate change is taking place, and when the respondents were asked how they perceive climatic event in their area over 10 years period, all of them said there have been an increase in temperature while 86.4% perceived decrease in rainfall. However, majority 75.7% of the residents are not aware that climate variability is taking place. The study further found that, respondents perceived the most experienced climate change risks as frost, drought and water scarcity, pest and diseases, heavy rain and hails, increased temperatures and floods and linked the risks with the effect of Irish potato production mainly through wilting and drying of Irish potato, poor production, increased pest and diseases, crop failure due to frost bite, rotting of Irish potatoes, poor germination, poor quality tubers, food shortage and also fast growth of Irish potato. Data subjected to inferential statistics using correlation analysis establish a strong positive relationship (r= 0.979) between long rains and r=0.896 in short rains and production. In temperatures, a weak positive relationship r=0.237 was established between minimum temperature and production while a negative relationship r= -0.381 between maximum temperatures and production was established. The study further established that majority of the respondents (82.1%), are practicing different technologies to adapt to climate change while only 17.9% have not yet changed their faming systems. Among the most used adaptation strategies include: practicing mixed faming, livestock keeping, changing planting dates, using of inorganic fertilizers/ use of chemicals, planting drought resistant potato variety and irrigating potato farms. The study concluded that climate change and variability is taking place and such changes are perceived to have serious effects to Irish potato production and therefore the study recommended that an accurate and timely weather focus should be provided in advance to help farmers prepare for any risks related to extreme weather events. There is also need for the government to initiate crop insurance to insure farmers in case of total crop failure. More so, more agricultural extension officers should be employed to educate farmers on the modern ways of farming to cope with climate change. This will improve their production as they will embrace using more resistant varieties as well as using improved technology.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

OPERATIONAL DEFINITION OF SIGNIFICANT TERMS

For the purposes of the current study, the following terms were applied to mean:

Adaptation: Refers to the adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates, harm or exploits beneficial opportunities.

Climate change: Refers to a change in the state of the climate that can be identified by changes in the mean and in the variability of precipitation and temperature that persists for an extended period—typically decades or longer**.**

Climate variability: Refers to variation in the mean states, on all temporal scales beyond those of individual weather events.

Households: A social unit composed of those living together in the same dwelling**.**

Perception: A process of recognizing and attaining awareness, beliefs, views and feeling of the environment through gathering, storing and interpretation of sensory information.

Resilience: Ability or capacity to emotionally cope or recover from a crisis or to return to pre-crisis status quickly.

Small- scale: Refer to small in size and limited in extent.

ABBREVIATIONS

AEZ : Agro-Ecological Zone

FAO : Food and Agricultural Organization

FGDs : Focus Group Discussion

GOK : Government of Kenya

IPCC : Intergovernmental Panel on Climate Change

MoALF: Ministry of Agriculture, Livestock and Fisheries

MDGs : Millennium Development Goals

NCST : National Council For Science and Technology

UNEP : United Nations Environmental Programme

UNDP : United Nations Development Programme

WRI : World Resources Institute

WTO : World Trade Organization

WWAP: World Water Assessment Programme

YRS : Years

CHAPTER ONE

1.0 Introduction

This chapter develops the background of the study. It highlights the nature of climate change and variability and the impacts of climate on agriculture and specifically on Irish potato production in Kenya. It explains the statement of the problem, articulates the study objectives, research questions and the research hypothesis that guide the study. The chapter also highlights the significance of the study, scope of the study and describes the study area.

1.1 Background of the Study

Climate change may be defined as any change in climate over time that is attributed directly or indirectly to human activity that alters the composition of the global in addition to natural climate variability observed over comparable time periods (Intergovernmental Panel on Climate Change [IPCC], 2007). It has generally been recognized that climate change is the biggest challenge facing mankind today. It has been identified as a threat to achieving Millennium Development Goal number one (MDG 1) of eradicating extreme poverty and hunger (United Nation Development Programme [UNDP], 2007) which just ended the year 2015. It influences almost all sectors of economic growth and development; however, the most affected sector is agriculture perhaps because climate is the main determinant of agricultural production. This is because climatic factors serve as direct inputs to agriculture; any change in climatic factors is bound to have a significant impact on crop yields and production. Studies have shown a significant effect of change in climatic factors on the average crop yield (Dinar *et al*., 1998; Seo & Mendelssohn, 2008; Mall *et al*., 2006; Cline, 2007 and Mbaisi, 2014).

The anticipated impacts of climate change and variability will continue to manifest in the form of floods, storms, frost and prolonged droughts and although the new set goals under the Sustainable Development Goals (SDGs) gives poverty reduction on the planet earth first priority, it is still unclear whether Kenya will achieve it by the target year of 2030, in the face of changing climate and other threats (Muthoni *et al*, 2017)

The Intergovernmental Panel on Climate Change Fourth Assessment Report confirms that climate change is here to stay and is anticipated to worsen mainly in developing countries where vulnerable people will be the worst affected. The report further argues that Africa and especially those countries lying south of the Sahara such as Kenya are the most vulnerable to climate change because of their geographical position which lies within the tropics (IPCC, 2007). The report further shows that during the 20^{th} century the continent of Africa has been warming at a rate of about 0.05°C per decade with slightly larger warming in the June–November seasons than in the December–May one (Hulme *et al*. 2001; IPCC, 2007). By 2000, the five warmest years in Africa had all occurred since 1988, with 1988 and 1995 being the two warmest years. This rate of warming is similar to that experienced globally (IPCC 2001). These would however cause a serious effect on the production of many crops with cereals doing well while horticulture would be destroyed.

The above backdrop was also supported by another report by the Kenya Climate Smart Agriculture strategies 2017-2026 which shows that climate change will have a range of positive and negative impacts in agriculture depending on the regions of the world. However, the report indicates that the negative impacts are expected to be more adverse in developing countries, particulary those in Sub-Saharan Africa such as Kenya which has experience increasing temperatures and other extreame weather events such as el-nino and La Nina.

Globally 80 per cent of the agricultural land area is rain fed and small-scale which generates 65 to 70 per cent of staple foods but 70 per cent of the population inhabiting these areas are poor due to low and variable productivity (Isha, 2012). Within agriculture, it is the small-scale rain fed agriculture that will be most impacted upon by climate change and climate variability. Temperature, precipitation and humidity are the most important weather parameters that will affect production of rain-fed crops. Rain fed agriculture is an important economic activity in the developing world. In East Africa, rain-fed agriculture is the mainstay of economic development with the majority of people living in rural areas depending entirely on it. However, this small-scale rain-fed agriculture is extremely vulnerable to climate change and variability largely due to the increasing temperatures, changing rainfall patterns and extreme weather events. Some crops are expected to experience more favorable growing conditions as a result of climate change, whereas others will find future climatic conditions intolerable to survive (Alemaw *et al*., 2013).

Agriculture is the mainstay of the Kenyan economy directly contributing 26 per cent of the GDP annually, and another 25 per cent indirectly. The sector accounts for 65 per cent of Kenya’s total exports and provides more than 70 per cent of informal employment in the rural areas. Therefore, the agricultural sector is not only the driver of Kenya’s economy but also the means of livelihood for the majority of Kenyan people (Government of Kenya (Gok) 2010). Yet, like other sub-sahara African countries, Kenya is dependent on small-scale rain-fed agriculture. Approximately75 % of Kenya’s population earns its living from rain-fed agriculture yet it is a drought prone country because of its eco-climatic conditions. The country contains a few climatic regions of high potential with regular annual rainfall average of above 2000mm. Studies by United Nations Development Programme (UNDP) puts 80% of Kenya’s land mass to be arid and semi-Arid, characterized by average annual rainfall of between, 200mm to 500mm per year, and are prone to harsh weather conditions (UNDP, 2006; Serigne, 2006). Such parts include parts of the Rift Valley, North Eastern, parts of Eastern province and Coast Province (UNDP, 2006). Due to the vast areas prone to drought, Kenya's vulnerability to food insecurity is the highest among the majority of small-scale agriculturalists in the region (UNDP, 2006).

Like in other parts of the country, farming in Nyandarua County is mainly rain-fed and farmers mostly practice small scale mixed farming, combining crop production and livestock keeping. Population is largely concentrated in rural areas (about 97%) with estimated equal distribution across the genders. There is a high dependency on Irish potato in the area for both consumption and commercial purposes. Despite the fact that the region has high potential for potato production there is low production and high poverty levels hence food insecurity. It is for this reason therefore that a scientific study was carried out to identify some of the cause of low production in the face of climate change and variability. According to Kenya Ministry of Agriculture, Livestock and Fisheries [MoALF, 2016), climate change and variation poses serious risks on the agricultural sector in Nyandarua with the major climate hazards frequently experienced in form of drought associated with moisture, heat stress, high temperatures, intense rain, and frost. The impact of intense rain is high in the Irish potato value chain since the hazard increases both production and marketing risks. Conversely, dry spells result in remarkably reduced yields arising from water scarcity and damage by frost.

Irish potato production and food security are intertwined. This is true because globally potato is ranked the fourth most important food crop after rice, wheat and maize. In Kenya it is the second most important food crop after maize. It is cultivated by over 70% of small-scale farmers and is the top of most important food crop in terms of human consumption. Apart from being source of food at household level, potato is a source of income for farmers especially in Nyandarua County. According to Waithaka (2017) Irish potato is an important crop in Nyandarua County for food security, employment and income generation. The value chain directly and indirectly supports 131,697 farm families in the County and has a net worth of over Kshs 7.0 billion. He further notes that Nyandarua County contributes 33% of warehouse potatoes produced in Kenya. However, this is no longer the same case especially in Ndaragwa constituency which is ranked the poorest region in the county. According to Abdi (2004) the divisions in Nyandarua ranks as follows in terms of levels of poverty beginning with the poorest: Ndaragwa, Ol Joro Orok, Ol kalou, Kipipiri, South Kinangop, North Kinangop. He points out that poverty in the county has been increasing over the year because AE zone LH5 (Ndaragwa) is becoming a semi-arid area.

The county for a long time has mainly relied on Irish potato production for its sustenance and since Irish potato production is becoming more sensitive to various types of natural hazards, it is vital to understand farmer's perception of climate change and variability and the adaptation strategies they are embracing to counteract the change, since the ability of farmers to perceive climate change is a key precondition for their choice to adapt. According to (Maddison, 2006., Deressa *eta*l 2010), adaptation to climate change is in two-step processes, that involves perceiving that climate is changing and then responding to changes through adaptation that improve productivity. This is confirmed by Hijman, (2003) who urgues that global potential potato yields decrease by 18% to 32% without adaptation and by 9% to 18% with adaptations. However, on many occasions extreme weather variability events hit smallscale Irish potato farmers unprepared and unable to cope. There is need therefore for scientific study to arrest the situation. Studies in the region have been done to document effects of climate change on small-scale farming, however most have focused on pastoralist communities and agriculture in semi-arid areas but none on Irish potato farming yet it is highly liable to suffer the impacts of climate change.

It is for this reason therefore that the current study investigated the effect of climate change and variability on small-scale Irish-potato farming in Ndaragwa Agro-ecological Zone, Nyandarua County, Kenya.

1.2 Problem Statement

Climate change and variability is unpredictable and so its impacts are unexpected and it varies with location, social economic and environmental conditions. According to Rosenweig, *et.al*, (1994) climate sensitivity of crops and farming systems are different across different climates and locations. For a given crop, under given technologies in a given location, agricultural yields increase with temperature up to a certain threshold and then start declining. There is a narrow optimal range for each farming system. There is need therefore, to analyze the sensitivity of crops to changes in climate to facilitate adaptations and advise farmers appropriately. Klein (2004) also suggests that in understanding climate change and variability effects and food in security scientific research is needed at the level that would specifically address specific geographic locations so that the communities will get adequate lessons to tackle climate change challenges with the precision that is necessary. To fill this gap the researcher narrowed down to Ndaragwa region in Nyandarua County to provide a wider scope on climate variability and change on small-scale Irish potato production including specific local places.

According to Abdi, (2004), Nyandarua County is considered one of the bread baskets of Kenya because of its high production of food crops like potatoes, cabbages, maize, beans, carrots, kales, tomatoes and peas that are sold largely in Nairobi and most other towns in the country. He further noted that, Irish potato is the primary staple food in the region, and it is a major component in almost every dish or meal served to Nyandarua people, with over 80% of the populations in the county engaging in the Irish potato production with some in value chain production. Most of the actors input suppliers' plants between 1-5 hectares while others are small-scale farmers.

Irish potato farming in the county is majorly rain fed thus very sensitive to changes in climate unfortunately, Climate change is happening as indicated by drought, floods, extremely low temperatures and frost that has led to frosts-bites, crop failure and famine and hence loss of livelihood and food insecurity. Studies show that the county has witnessed a change in Climate since 1981 and the weather patterns have changed (GOK, 2013). Previously the county did not have distinct rainfall seasons as it is the case now, it experienced rainfall throughout the year but nowadays there are two rainfall seasons with the long rains in March to May and short rains from September to December which are still unpredictable. These changes have also changed the farming patterns in the county as some areas such as Ndaragwa agro-ecological zone experiences some periods of famine, floods, frost and most cases of crop failure have also been common due to extremely low temperatures at night leading to frost bite (Republic of Kenya [ROK], 2013).

The trio effects of drought, floods and frost bite from low temperatures present a unique situation as far as studies on climate change on agriculture in Kenya are concerned. Previous research on climate change and variability in Kenya, despite the complexity outcome of climate variability, have concentrated on precipitation and temperature increase ignoring decrease in temperature that leads to frost bite, a major challenge to Irish potato farming in the study area. The current research incorporated this with a nuanced understanding of the impact of climate change and variability to Irish potato farming in respect to precipitation, temperature rise and falls emerging directly from the knowledge of community experiencing such weather extremes. This is important because if we understand how people perceive an aspect (climate change) and operate on it, it makes the future prediction more precise and accurate. According to (Okaka, 2016; Leiserowitz, 2006), personal understanding and perception of risk is the strongest motivation of behavioral change and how people respond to hazards. Elsewhere Gbetibouo (2009), points out that Farmers' ability to perceive climate change is a key precondition for their choice to adapt. This therefore calls for a need to increase knowledge, perception and awareness in the region which has a limited knowledge on the impact of climate change on small-scale Irish potato farmers in central Kenya, specifically on arid and semi arid lands as most researchers have focused on pastoralists and other farming systems in arid and semi-arid areas.

Coe *et al* (2011) states that, the starting point for understanding the effect of future climate variables needs the understanding of the current situation. The author further emphasizes that we have the tools but more effort is needed to make the data available, build climate analysis into every agricultural project and bring relevant and accurate climate information to farmers.

1.3 Objective of the Study

1.3.1 General objective

The general objective of this study is to investigate the effects of climate change and variability on smale-scale Irish potato crop production in Ndaragwa region, Nyandarua County, Kenya.

1.3.2 Specific objectives

The specific objective that guided the study were as follows:

1. To establish the nature of the variability and change in temperature and rainfall in Ndaragwa Agro-ecological zone;
2. To determine the small-scale Irish potato farmers' level of awareness of climate change and variability;
3. To assess small scale Irish Potato farmers' perception of the effects of climate change and variability on potato production;
4. To establish the relationship between Climate elements and Irih potato production in the region; and
5. To examine the practices and technologies related to climate change adaptation and Irish potato production among the communities in Ndaragwa.

1.4 Research Questions

The following questions were formulated in order to guide the study

1. What has been the pattern of the variability and change in temperature and rainfall in Ndaragwa?
2. What is the link between Irish potato yield and variations in climate elements in Ndaragwa?
3. In which ways are the Irish potato farmers affected due to climate change in the study area?
4. What are the adaptation strategies that small-scale Irish potato farmers employ to mitigate the adverse effects of climate change in Ndaragwa?

1.5 Research Hypothesis

The following hypotheses were tested in this study

H_{O1}: There is no significant relationship between Irish potato yield and rainfall variability in Ndaragwa A.E Zone**.**

H_{O2}: There is no significant relationship between Irish potato yields and temperature (minimum and maximum temperatures) variability in Ndaragwa A.E.Z.

1.6 Significance of the Study

The issue of poverty eradication and food security has dominated policy document and academic research in the last decade. In fact, the sustainable Development Goals (SDGs) number 1 and 2 is about eradicating poverty and end hunger and all forms of malnutrition by doubling agricultural productivity and incomes of small-scale food producers. The results of this study therefore are important as it generates new knowledge on innovative ways Irish potato farmers in local communities in Kenya are coping with climate change induced drought and frost bite and weaknesses abound. The study result also provides important insights for policy formulation in the agricultural sectors on the climate change impact on Irish potato production and food security in Kenya. In this concept, the study area is one of the unique regions in Kenya affected by both high temperatures as well as low temperatures that lead to frost bite. This gives a clear picture on how different geographical regions are differently affected by climate change and variability and has emphasis on the benefits of assessing different locations so as to strategize ways to counteract climate change risk differently. This is important for policy legislators to have candid understanding that policies on effect of climate change should be formulated basing on different geographical location. Finally, the study will be contributing to the pool of knowledge on effects of climate change and variability from the people's perception which should inform scientific and policy marker decisions on climate change by incorporating people's views and idea and besides contributing to the pool of knowledge, the study results also forms a basis for further research.

1.7 The Scope of the Study

The study confines itself in establishing the impacts of climate change and variability on Irish potato production in Ndaragwa Agro-ecological Zone (A.E.Z). Irish potato is critical to food security since it is the second most important food crop after maize and it contributes highly on the overall dietary energy. It is also the main activities in Ndaragwa region creating employment, income generation, poverty eradication as well as for economic growth and development. The study used data on respective variables in the period between 1985 and 2018. This period is long enough to capture how the climate changes are translated into the changes of potato crop production in the region. The study focuses on influence of temperature and rainfall on Irish potato crop and due to data limitations, the study did not consider several other explanatory variables such as radiation, atmospheric concentration of CO_2 and humidity.

1.8 Study Area

The study was carried out in Agro-ecological zone LH5 (Ndaragwa) which is located in Nyandarua county. The geographical position of the county lies between $0^{0}8^{'}$ to the North and $0^{0}50^{'}$ to the South and between $35^{0}13^{'}$ East and $36^{0}42^{'}$ west of the Aberdare mountain Ranges. It borders five counties, Laikipia to the North and North West, Muranga and Nyeri to the East, Nakuru to the West and South West and Kiambu to the South. The county covers an area of 3,304km^2 and it has five Administrative Constituencies namely: Ndaragwa, OlJororok, OlKalau, Kinangop and Kipipiri with 25 divisions, 73 locations and 182 sub-locations (GOK 2013). The name Nyandarua is of

Kikuyu origin meaning “Pegged Skin” and this is because of the Aberdare Mountain Ranges that resembles to an animal skin pegged to dry.

Figure 1.1 shows Ndaragwa agro-ecological zone that covers an area of 653.5 km^2 at an altitude of 2405m above the sea level. It is located at 0^0 07’s and $36^0 52^{'}$E. it is one of the five constituencies in Nyandarua County. The constituency has four wards including: Kiriita, Leshau pondo, Ndaragwa central and Shamata ward. Ndaragwa agro-ecological climate is classified as warm and temperate with the average annual rainfall of 1346mm with the least amount occurring in February while the greatest amount occure in the month of April (*climate-data.org, 2019)*

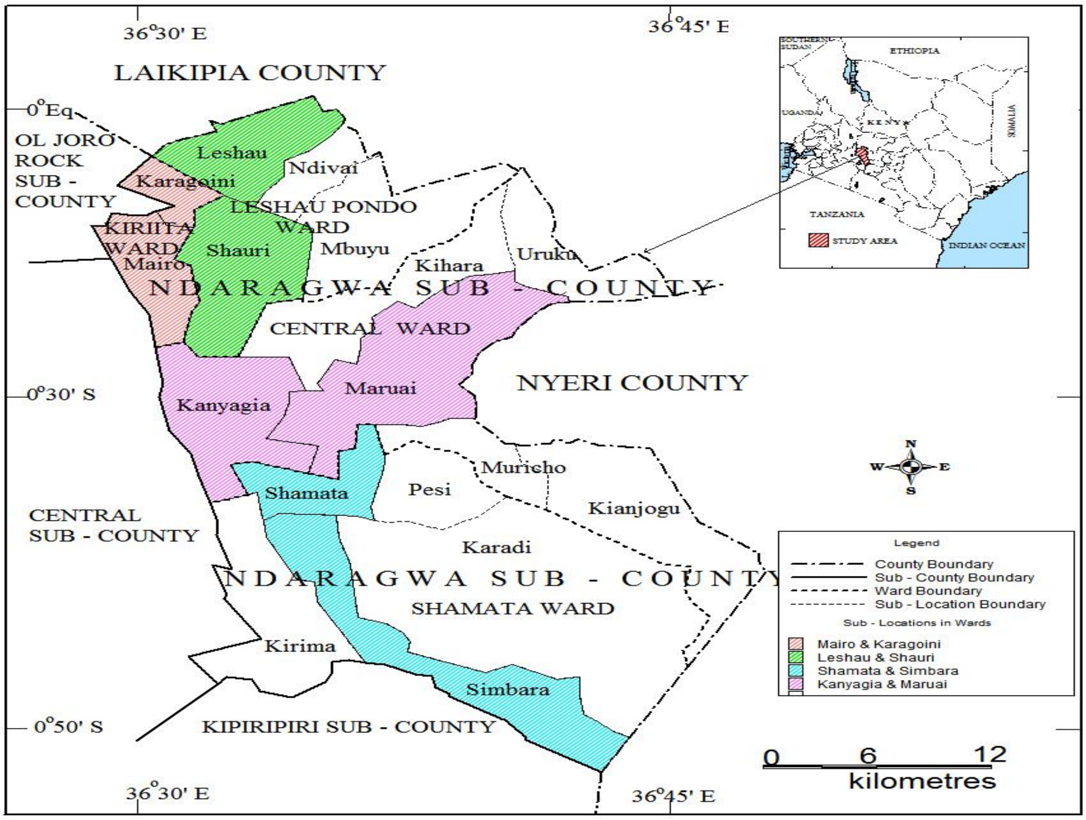


Figure 1.1 Showing Ndaragwa sub-county and its wards

Map of Ndaragwa Sub – County showing sub – locations in each ward as study area.

Source: Moi University geography Department GIS Lab.

1.8.1 Bio-Geophysical factors

The geomorphology of the county was structured by endogenic processes, faulting and volcanic eruption forming one of the most outstanding features in the Kenyan Geography - the Aberdare ranges, kinangop plateau and OlJor-orok plateau. The highest point of the Aberdare ranges is at 3999m above the sea level.

The county's largest water body is Lake Ol'bollosat that receives water from streams and underground water seepage from Aberdare ranges and Dundori hills. However, the lake is experiencing a lot of encroachment, which poses risk on its survival. The county also has eight permanent rivers: Malewa, Ewaso Narok, Pesi, Turasha, Chania, Kiburu, Mkungi and Kitiri rivers which feed most of the area with water for household use. (Nyandarua County Government, 2013)

The report further points out that some areas in the county are in the highland savannah zone, characterized by scattered trees with expansive grass cover. In elevated areas, tree cover increases forming thick forests with thick undergrowth. However, most of the natural vegetation has been cleared leading to environmental hazards such as environmental degradation which has claimed large portions of arable land. This has had some negative effects such as reduced rainfall, global warming, soil erosion, climate change, poor health and reduced food production.

1.8.2 Climate and soil

Nyandarua's climate is classified as warm and temperate. It's basically influenced by the Aberdare Ranges. In Nyandarua, long rains are received from March to May with a maximum rainfall of 1600 mm and short rains from September to December and with a maximum rainfall of 610 mm to 700 mm in the lower region or semi-arid areas of Ndaragwa. The rainfall intensity varies according to the location with areas near the

Aberdare slopes receiving sufficient rainfall and the plateau receiving scanty and erratic rainfall (MoALF, 2016)

The county has moderate temperatures. The highest temperatures are recorded in the month of December, when the mean average is 21^{0} C and the lowest temperature is recorded in the month of July, with a mean average of 7.1^{0}C. The county also experiences temperatures with adverse effects. The cold air that is generated during clear nights on the moorlands of Nyandarua Ranges flows down the Kinangop Plateau and Olkalou Salient causing night frost nearly every month of the year making cultivation of maize, tomatoes and to the extreme potatoes too hazardous. The valleys west of the plateau occasionally provide outlet of the stream of cold air. The temperatures range between 1.2^{0}C to 10^{0}C. The low temperatures last some few hours before sunrise though they cause a lot of frost bite. (MoALF 2016).

Aberdare ranges also determine the climate and weather patterns of Ndaragwa area. Some of these aspects include temperature, rainfall and humidity. Ndaragwa experiences rainfall that ranges between 700mm-1000mm with long rains in April-July and short rains in November, hence causing some parts of the area to be classified as semi-arid (MoALF 2016). The rainfall distribution pattern is bi-modal, that is there are two rainy seasons. The main season that is commonly called long rains begins in March May affecting the harvest in October and the second season begins in October to December affecting the harvest in February the peak is in July-August. The temperature varies with altitude and local wind patterns. The mean temperature is 23.5^{0}C with little monthly variations (Nyandarua County Government, 2013**).** Extremely cold winds originate from the moorlands of the Aberdare Ranges and blow to Ol' Bolossat valley decreasing the temperature to about 12^{0}C. They bring about frost which destroys food crops especially potatoes and grass. The cold winds are trapped in the valley and hence the area experiences night frost nearly every month of the year. Instability of the air at the Equator causes rain especially in July. The highest temperatures are experienced in December and January. Extremely cold temperatures occur in July- August.

The county's soils vary from different zones both in fertility and distribution. It is of volcanic type which has moderate to high fertility. Some parts of the area like Kinangop and OlKalau plateau have poorly drained clay soils while other areas like Ndaragwa, Northern part of OlJoro-orok and OlKalau have well drained clay loam soils making them to have different potentials for crop production (Nyandarua County Government, 2017).

1.8.3 Social-Economic profile

The current population Census for 2019 has indicated that the population of Nyandarua County is 638,282 persons with 315,022 males, 323,247 females and 20 intersex persons Kenya National Bureau of Statistics (KNBS, 2019). The report also indicates that Ndaragwa constituency has a population of 98,698 persons with 48,486 males, 50,210 females and 2 intersex persons with 27,917 Households and 3.5 average household sizes.

The projected populations by (KNBS, 2013) which was estimated to grow at 2.4 % annually also seem to contrast the result for in 2013, the population was projected to be 656,348 persons comprising of 321,593 males and 334,755 females, 688,618 and 722,498 persons in 2015 and 2017 respectively with 43% of the population being below 15 years while over 69% of the population is below 30 years.

The population in the county is more or less evenly distributed and does not seem to follow a particular pattern. However, there is a tendency for most of the people to be concentrated in the major urban areas like Njambini, Engineer, Mairo-inya and Ol'kalou.

The census report also projected that the population density of the county keeps increasing every year where it was estimated to be 202 persons per km^2 in 2013 and 264 persons per km^2 in 2017 and in Ndaragwa 172. However, the current census reported that the density on Nyandarua is 194 persons while that of Ndaragwa is 187 persons.

1.9 Economic Activities

The main economic activities carried out in the county are crop farming and livestock keeping. Most of the land in the county is under small holder and medium farms. The main crops grown include potatoes, maize, beans, carrots, cabbages, fruits and peas. There are also some farmers who grow wheat as cash crop; however due to its high cost of production which majority cannot afford, it is only grown by a few. Livestock farming is also a major activity in the county for it lies in the high potential area for livestock production and the main animals reared are indigenous and exotic species of cattle, goats, sheep, rabbits and poultry. Dairy farming is the dominant enterprise in the livestock subsector. Bee keeping is also being practiced by several farmers in the region. The main value addition activities on livestock products include milk processing, cooling of milk, processing and packaging of honey and leather tanning. Most of these activities are on a small scale (Nyandarua County Government, 2013).
Nyandarua County also has the tourist attraction sites like Lake Ol'Bolossat, Thomsons Waterfalls and Aberdare Ranges National Park. However, the poverty levels are high with 46.6 percent of the total population living in absolute poverty, and it's the poorest county in central Kenya yet it has the highest potential (KNBS *et al,* 2013). The report associated it with the high dependence on agriculture by most people in the county and

resource inequality that lead to higher poverty level in some areas compared to others. According to Abdi (2004), Ndaragwa is the poorest area perhaps because of climate viriability that makes it a semi-arid area followed by OlJoro-Orok, Olkalou, Kipipiri and kinangop which is known to be the most productive area.

1.10 Agriculture and Potato Production

According to (MoALF, 2016) Irish potato is grown mainly for subsistence. It is a major component in almost every dish/ meal for the people. Commercial production is common in AEZ UH1 (South Kinangop) and UH3 (Olkalou, Oljoro-orok and Ndaragwa). The crop is grown in both the dry (first) season (usually extending from September to December) and the wet (second) season (usually extending from March to May) by small-scale farmers who depend on rain and family labour.

Although Nyandarua is one of the largest potatoes producing county in Kenya, the average yields have remained at less than 10 t/ha compared to on-station figures of 30-60 t/ha (Nderitu *et al*, 2014). The major variety that has been grown in the region includes Asante, Desaree, Shangi, Dutch Robjin, Kenya Karibu, Kenya Mpya, Kenya Mavuno, Tigoni and Sherekea. However, many of these varieties like Kenya Karibu, Tigoni, Desiree and Kenya Mavuno suffered the biggest weight loss over the 8-month storage period compared with Dutch Robjin because, tubers of these varieties were not fully mature during harvesting due to the long rains leading to early sprouting and hence excessive weight loss during the subsequent storage as many farmers store their seed potato tubers in dark stores instead of using better techniques such as diffused light stores.

These has led to Over reliance on Shangi, which is the dominant variety due to its market preference, early maturity, short dormancy and farmers are able to grow potatoes 3 times a year and practice staggered planting and harvesting throughout the year (Nyandarua County Potato Strategies, 2017-2021). The report however indicated that over reliance on rain-fed production of potatoes in the County has seen a serious decline because the county has been experiencing erratic rainfall which cannot sustain production. Nderitu *et al* (2014) also reported that the rains in the region have dwindled in certain years compared with their levels in the 1980s and that changed weather patterns with erratic rainfall patterns have negatively affected potato productivity, particularly when unsprouted or even poorly sprouted seed is used by farmers for planting. The county however has high potential for irrigation production which has not been harnessed and it is endowed with permanent rivers and suitable sites for dam and water-pan construction.

CHAPTER TWO

LITERATURE REVIEW

2.0 Introduction

The purpose of this study was to establish the impacts of climate change and variability as perceived by small scale Irish potato farmers in Ndaragwa agro-ecological Zone of Nyandarua County. This chapter therefore summarizes literature reviewed that is utilized to conceptualize the research question. The sections provide an overview of the concept of climate change and variability, farmer's perception and awareness on climate change and variability, impacts of climate change and variability on Irish potato production and the coping mechanism to mitigate impacts of climate change on small scale-Irish potato production. The chapter also discusses the theoretical and conceptual framework that guided the study. `

2.1 The Nature of Climate Change and Variability

One may ask, is climate change and variability real and happening? A number of authors have indicated that climate has been varying and eventually changing in different geographical regions, which is evidenced by increasing global average temperature that has warmed with 0.8°C in the past century and 0.6°C in the past three decades, melting ice and snow, rising sea levels and increasing climate variability (Hansen *et al.*, 2006**;** Frumkin, *et al*., 2008; IPCC, 2007). IPCC (2001) report also shows that the climate of Africa is warmer than it was 100 years ago and model-based predictions of future green house gas induced climate change for the continent clearly suggest that this warming will continue and, in most scenarios, accelerate. This report continues that the five warmest years in Africa had all occurred since 1988, with 1988 and 1995 being the two warmest years. This rate of warming is not dissimilar to that experienced globally, and the periods of most rapid warming—the 1910s to 1930s and the post-1970s—occur simultaneously in Africa and the rest of the world.

In 2007, The Intergovernmental Panel on Climate Change (IPCC) reports that there is a statistically significant increase in the global mean state of the climate or in its variance and further increases are expected if carbon dioxide (CO_2) and greenhouse gas (GHG) emissions are not controlled. Moreover, there is a general agreement that the earth's climate is undergoing changes, and observations are consistent with scientific expectations regarding the increasing concentration of GHG in the atmosphere. Dai (2006) found that changes in extreme weather and climate events, such as heat waves and droughts, are the primary way that most people experience climate change. The authors indicate that human-induced climate change has already increased the number and strength of some of these extreme events and over the last 50 years, much of the region has seen increases in prolonged periods of excessively high temperatures, heavy downpours, and in some regions, severe floods and droughts. Besides increases in temperature, climate change in Africa is expected to cause, increases in the incidence of extreme events such as droughts and flood changes in rainfall intensity, increases in desertification and increased in drought frequencies (Niang, *et al.*,2014*;* Alemaw *et al.*, 2013*;* Riech *et al.*, 2001).

According to Okoth *et al (*1995) indicated that climate variations in Africa have manifested through shifting of dry lands boundaries and the rise and fall of water levels in many lakes. Giving examples, the author reported that the tropical North African monsoon winds were stronger than they are today and large parts of the Sahara regions were vegetated and inhibited by wildlife. Coumou *et al* (2016) points out that climate Changes in sub- Saharan Africa are not uniform across the region. The authors found that East Africa is at higher risk of flooding and concurrent risk of drought cases in some areas. West Africa is projected to experience severe impacts on food production, including declines in oceanic productivity, with severe risks for food security and negative repercussions for human health and employment while South Africa sees the strongest decrease in precipitation with concurrent risks of drought.

Kenya has also realized the changes brought by Climate change and variability that have impacted on the country's economic development and threatens the realization of Vision 2030. In the scenario that GHG emissions will continue to grow over the next decades, there is strong evidence that the effect has result not only in changes in the mean weather conditions, but also in increase of the variability of climate (IPCC, 2012; IPCC, 2007). According to the World Resources Institute Climate Analysis Indicators Tool (WRI CAIT, 2007), agriculture was the leading source of GHG emissions in Kenya in 2013, contributing 62.8% of total emissions, excluding the land-use change and forestry. Within agriculture, 55% of emissions were due to enteric fermentation from livestock and 36.9% due to manure left on pasture. Energy was the second largest source of emissions (31.2%), with other fuel combustion and transportation contributing 74.3% of energy emissions. Industrial processes (IP) and waste contributed 4.6% and 1.4%, respectively. This has resulted to increased cases of drought and famine. For example, drought is the prime recurrent natural disaster with recent occurrences in 1983/1984, 1991/1992, 1995/1996, 1998/2000, 2004/2005, and 2008/2011, with each of these events causing severe crop and livestock losses, famine and population displacement (GOK, 2012).

In another report by (FEWSNET, 2010), large parts of Kenya have experienced more than 100mm decrease during long rain season as at 2009, and recent La Nina years tend to be drier whereas El Nino years tend more towards average rather than above average rainfall. However, in 2013, the National Climate Change Action Plan (NCCAP), indicates that, excessive floods in Kenya occurs relatively frequently (on average every three to four years) and is linked to El Niño or La Niña episodes that can lead to extreme weather in the country and region. Annual rainy seasons in Kenya are becoming progressively wetter, with sudden and/or late onsets bringing with them floods and inundation. The report still says that major floods periodically afflicts the Winam Gulf of Lake Victoria, Lower Tana basin and the coastal regions. Geographically, the western, northern, eastern, central and south eastern parts of the country are quite susceptible to seasonal floods in the wet seasons of March-April-May and October-November-December. Riverlines floods are the most dominant floods in Kenya, although the arid and semi-arid lands (ASALs) are particularly vulnerable to flash flooding.

Conversely, Mbaisi (2014) indicated that most of the Kenyan rift valley lakes including lake Turkana, Baringo, Bogoria, Nakuru, Elementaita, Naivasha and Magadi had each occupied a much larger area in the Holocene period than today due to fall on water levels. The author further points out that the occurrence of lake sediments including the diatomite around some of the lakes is a pointer of climate change in Kenya. A report by RoK (2010) also shows that rainfall was recorded to have decreased by 2.6% between 1960 to 2006 and projected to decrease by average 15.6% by the year 2050. The report further indicates that climate change introduces an additional uncertainty into existing food insecurity; particularly in the ASALs which cover over 80 per cent of the country. These increased temperatures in the future are likely to exacerbate the drought conditions and may have a significant impact on water availability, prolonged droughts, and increase cases of landslides during flood events and changes in river regimes including river courses.

In Nyandarua region, rare extremes such as frequent frosts events have been experienced in the recent past, which are as a result of abrupt, sharp temperature gradients that attain the threshold temperature values for frost formation. These temperature extremes often occur on weather time scales that require daily or higher time scale resolution data to accurately assess possible changes (Nyandarua County Government, 2017). Furthermore MoALF (2016), report indicates that climate in Nyandarua has already been observed to change since 1981; the first wet season has experienced a moderate (1ºC) increase in mean temperature and associated reduction in crop cycle, and a slight tendency for increasing precipitation while the second wet season experienced a mild (~0.5ºC) increase in temperature, and no change in precipitation. The report further indicates that, looking to the future in the years of 2021-2065, prolonged moisture stress is projected to occur across both seasons of the year analyzed, whereas intense precipitation looks to change little. Within 30 years (by the early 2040's) temperature is projected to increase by 0.3ºC, with the first wet season projected to experience even greater changes.

Today, climate change can be detected through changes in the average patterns of climate parameters like rainfall, temperature, wind and pressure, storm surges, flooding, heat extremes and water scarcity. The Intergovernmental Panel on Climate Change (IPCC, 2007) has also recommended indicators that can be used to detect climate change. Some of these indicators include the "number of nights with temperature below/ above certain threshold values", cold and warm spells indicators, the daily temperature range, extremely wet days, and the number of heavy precipitation days. Despite the recommended indicators to detect climate change and variability most studies on climate change focus on rainfall and temperature increases and have generally ignored areas experiencing temperatures below certain threshold values. While addressing the problem of climate change and variability in Ndaragwa Agro-Ecological Zone, the current study addresses the changes by analyzing rainfall, maximum as well minimum temperature in the region.

2.2 Farmers Perception and Awareness on Climate Change and Variability

Climate change and variability causes serious change that most farmers are aware of although the majority do not call it climate change but rather bad weather (Okaka, 2016). Climate variability is defined as the way climate fluctuates yearly above or below a long-term average value while Climate change is a long-term continuous change (increase or decrease) to average weather conditions or the range of weather (IPCC 2007). It varies over seasons and years instead of day to day like weather, some seasons are colder than others while some years have more overall precipitation. Even though people are fairly perceptive of climate change, it is not as noticeable as climate variability because variability happens over seasons while climate change is noticed after an analysis is done for about 30-35 years. Climate change is slow and gradual, and is unlike year-to-year variability, which makes it very difficult to perceive without scientific records.

Several studies carried out in Africa, indicate that a lot of environmental shocks such as flooding, drought and water logging are experienced lately, influencing farmers perception. Deressa (2010) in a study in Ethiopia covering the period between 1965 and 2009, noted that Ethiopia had encountered droughts about ten times and that during these times the region was affected by eight of the drought hazards indicating how susceptible the region was to vagaries of weather. It is through such events that most farmers perceive the reduction of crop production that result to food insecurity. Generally, farmer's perceptions are partly based on past observations with key interest on the recent climatic events to form their perceptions of climatic conditions and to make their decisions about adaptive behavior (Maddison, 2006). However, it is possible that farmers' opinions are influenced by others through communal interactions.

Most of African countries are experiencing extreme climate variability and change which has influenced many African governments to embrace new approaches on climate change by encouraging their citizens to plant more trees and maintain ecosystems like forests and wetlands. However, this is taking a slow movement since in some areas people are illiterate and lack awareness of climate change variability hence cutting down trees. Schelenker and Lobell (2010) reiterate that farmers in many parts of Sub Saharan Africa, one of the regions facing impacts of climate change, are illiterate and lack western style education. This may affect their perceptions and behavior towards issues of climate change. However, it has been observed that many people of Africa rely on their traditional institutions which are highly knowledgeable of happenings and changes in their environment. Knowledge is even much more important in African society where many farmers who are often accused of clearing vegetation are the least educated.

In a later study in Africa, Juana *et.al* (2013), found that most farmers in Sub-Sahara Africa are aware that the continent is getting warmer, and precipitation or rainfall patterns have changed. However, changes in precipitation patterns are different for different regions in Africa. While farmers in southern and East Africa reported that they have experienced drier conditions with increased frequency of droughts, farmers in West Africa have experienced wetter but shorter rainy season. Observed trends of temperature and precipitation tend to support farmers' perceptions. The implication is that farmers need to adjust their agricultural management practices to ensure that they make efficient use of the prevailing precipitation patterns in the different countries or regions. The study also shows that in all regions, farmers have perceived changes and fluctuations in the climate over the last ten years, annually and seasonally. The socio-economic parameters that proved to be significant as a whole were labour and input costs.

In South Africa, Gbetibouo (2009) argues that farmers with access to extension services are likely to perceive changes in the climate because extension services provide information about climate and weather. Consequently, awareness and perceptions of changes in climatic conditions shape action or inaction on the problem of climate change.

Elsewhere in Bangladesh, Haque *et.al* (2012) found that majority of the farmers (95%) reported that temperature during summer months has increased, while 80.2% farmers reported that the rainfall has decreased. They also perceived that climate variability was negatively affecting the agriculture, human health and livelihoods as a whole. That there is a significant relationship between small-holder farmers' perception of floods and droughts and adoption of conservation practices such as zero tillage, crop rotations, application of organic fertilizers. However, the authors found that farmers perception on conservation agriculture as a climate change adaptation strategy was very low.

In another study in Bangladesh, Uddin, *et.al* **(**2017) found that the majority of farmers perceived an increased trend of repeated short winter seasons, long summer seasons, unpredicted rainfall and changes of the monsoon season. They argued that increasing temperature along with decreasing precipitation may enhance the water scarcity resulting to drought, which in turn, may affect crop production output. By using the logic model, they found that out of the nine factors surveyed; education, family size, farm size, family income, farming experiences, and training received, were significantly related to the farmers' perception of climate change and identified as influential factors of farmers' perception of climate change.

Fanen *et.al*, (2014), in their study on the assessment of farmers' knowledge and perception about climate change in Savannah region of Nigeria, found that all of the respondents were aware of climate change. However, less than 10% were aware of some of the scientific controversies surrounding the climate change debate. Their result further shows that majority (96%) of the respondents have heard about climate change and are aware of its occurrence and impacts in their community, about 44% of these have heard of climate change for the first time through word of mouth from relatives, friends, government officials and officials of non-governmental organizations and 31% heard of climate change for the first time on radio, while 26% heard about climate change for the first time on television. They added that, people generally associated climate change with temperature and precipitation. More than half of the respondents associated climate change with vegetation change; however, none of the respondents associated climate change with wind pattern. The study also captured the statement by one of the respondents who said that, "in this place [community] one can never predict rainfall and temperature conditions anymore … there is change every time for the last few years … the temperature has been increasing with increasing period of dry season, but last year was different … the rain was so much that all our farmlands and houses were washed away … now even to get firewood is a problem".

Bryman (2008) and Sleger, (2008), suggested that farmers perceptions on climate variability influence their adaptation since it influences their agricultural planning and management decisions. They also revealed that adaptation to climate change and variability requires that farmers must first realize changes in the climate before they can identify and implement potential useful adaptation strategies. Using treatment effect model, Dennis *et.al,* (2016) in their study, find out that 69.5% of 240 cocoa farmers perceived an increase in the average temperature while 22.5% perceived an increase in the average rainfall over the years and that farm size, farm management training, household size and Farm-Based Organization (FBO) influenced farmers perception.

According to Juma (2015), farmers in Tanzania define climate variability as bad weather whereby the amount of rainfall is less sufficient, erratic and unpredictable. That it is essentially dry and hot characterized by crop failure, water scarcity for humans and for pasture development. Normally, this kind of a year culminates into hunger. In West Pokot in Kenya, Binyanya (2015) found that 68% of the farmers felt that the local climate had greatly changed as compared to past and they termed it as being ‘’bad’’ at the moment and talked of frequent dry spells mostly caused by seasonal shifting of the short and long rains and increased variability of temperatures especially in the low potential zones. Mutembei *et.al* (2017) also found that 75.3% of the respondents were aware of climate change. The findings confirm that education level influences climate change perception and response. This study also reveals that a considerable level of climate change awareness exists among farmers in Mwea region. Farmers in this area are highly exposed to climate risks based on their dependence on rain-fed agriculture as the main source of food. The study further concludes that, Radio is a powerful media that can effectively be used to relay information on climate change adaptation strategies and early warning to farmers.

In another study in Kenya, Ochenje *et.al,* (2016) found that farmers with larger farm sizes were more likely to agree that climate change is there and is affecting water resources at farm level by 1 percent. They also found that farmers with a larger piece of land would experience greater loss caused by climate change effects on water resource than farmers with smaller pieces of land leading to higher perceptions. With the looming water scarcity at the farm level, farmers with larger pieces of land may not be able to maintain farm productivity leading to yield reductions. This implies that perceptions depend on the impact of climate risk to the farmer and therefore awareness of climate change and promotion of adaptive technologies by the government should consider the vulnerability of the farmer towards the climate change risks. Ochenje *et.al* (2016) concludes that the level of perception of climate change determines how the farmer will respond to the negative effects of climate change. The study also reported that access to climate change information through extension officers or through radio enhances farmer's perception to climate change. The government should therefore put more effort to come up with programs that can help to disseminate climate change information to the farmers since awareness of climate change plays an important role in climate change adaptation. They recommended that, government should also invest in extension staff to enable farmers to easily access the extension services.

Information is power, therefore the knowledge and awareness on climate change by many farmers through extension officers who disseminate information of climate variability and change, tend to educate farmers to embrace smart farming as an adaptive method. However**,** although many studies found that farmers are aware of climate change and variability, the current study not only assessed farmer's perception on climate change risks but also addressed the measures that the respondents have taken to adapt to effects of climate change.

2.3 Impact of Climate Change and Variability on Irish Potato Production

Among the non-cereal crops, potato is the most important food crop, ranking third after wheat and rice, in the world because of its ability to grow in the high altitude areas where maize does not do well and can also grow well in areas suitable for maize (medium altitude and lowlands) its high nutritive value (in terms of calories, vitamins, proteins, potassium and fiber); its high production per unit area and time (can have three crops per year); its value as a cash crop; it is labour-intensive and generates employment in production, marketing and processing sectors; and has potential as an industrial crop in the manufacture of starch, pharmaceutical carrier material, soap, alcohol, biogas generation and animal feeds (MoALF, 2016).

According to Janssens *et al* (2013), Irish potato crop is grown mainly in cool, high altitude areas with well distributed rainfall. The most suitable elevation is between 1,500 metres and 2,500 metres above sea level. The authors also pointed out that main potato growing areas in Kenya are found in Central, Eastern and Rift Valley regions with Central region producing more than 53 percent, while Eastern and Rift valley regions produce a combined total of 44 percent. In the Eastern region, the main growing region is the Meru district in the areas around the slopes of Mount Kenya, in Central region, nearly all the counties produce some potatoes, with Nyandarua county being the largest and most diversified potato producing area while in Rift Valley, potatoes are grown in the Mau escarpment region in Dundori, Mau Narok and Molo, and in the western highlands of Kericho, Bomet and Uasin-Gishu counties .Nyandarua County contributes about 33% of the total potato produced in Kenya Janssens *et al* (2013).

Despite the increasing demand for Irish potatoes in the country, production of this commodity is still low and at the moment potato prices are at an all times high (The Organic Farmer TOF, (2008). According to KARI, (2005) & MoA (2006) average Irish potato output has not been increasing at farm level and the trends in national Irish potato production show that during the past 20 years there has been no significant increase in productivity and the average national yield is less than 10 metric tonnes per hectare compared to a potential of 25-35 metric tonnes per hectare on research station and an expected 14.5-20 metric tonnes per hectare under farm-level conditions. The decline in production is associated to among others climate change and variability (Orina 2009).

According to Frank *et al* (2014), the net effects of climate change on potatoes will either have positive or negative effects depending strongly on the specific production regions and ability of farmers to adapt production practices to changing conditions. This compares favorably with Muthoni, (2017) & Spore, (2015) who indicate that Impacts of climate change might be positive or negative depending on regions although they also said that, for many regions global warming will bring about a decrease in production due to changes in annual and seasonal rainfall, more erratic weather patterns and more intense and frequent extreme weather events such as heat waves, drought, storms and floods .This indicates mixed impact on potato production implying uncertainty and therefore need more research in different spatial and temporal (time to time) over the Earth surface.

Conversely, Coumou *et al* (2016) said that, while some crops would respond positively to elevated Cabon dioxide ($Co_{2)}$, the associated impacts of elevated temperatures, alters patterns of precipitation and increase frequency of extreme events such as drought and floods which depress crop yields and increase production risks including shortening or disrupting growing seasons, reduction in the areas suitable for agriculture and declining agricultural yields in many regions of sub-saharan Africa.

2.3.1 Impacts of Rainfall on Irish Potato Production

Today, climate is unpredictable, rainfall delays and sometime not sufficient to sustain germination, this leads to replanting of the seed which increases the cost of production Mbaisi, (2014). Intense rainfall has damaged potato production in recent years where heavy rains during planting seasons cause significant loses through seed decay which further increases the cost of production in replanting and use of herbicides to control massive diseases caused by pathogenic bacteria that damage quality of tubers and decline yield Jovoviv *et al* (2016)

According to The Star (2019) report on potatoes at risk of climate change indicates that the British public could see chips wiped off from menu if unpredictable weather continues in this trend. In the report, Irish potato production saw a 20% drop last summer compared to the previous season as a result of heat waves and drought and by the 2050s; climate projections suggest the amount of land that is currently well-suited for potatoes could decline by three-quarters. The report also found that Campaigners have warned that extreme temperatures driven by climate change, could damage future potato yields and threaten the much-loved British chips.

Elsewhere in South Africa, Kabanda (2011) on a study of Irish potato production trends between 1991 and 2003 established that rain fed Irish potato production was leading with 50.8% while irrigated Irish potato lands produced 49.2%. However, the author found that by 2002/03 the rain-fed potato production shrunked to approximately 22% while the irrigation systems increased to the tune of 78%. These led to most potato farmers that could not afford irrigation technology shift to maize production.

Irish potatoes show high sensitivity to water stress either waterlogged or drought stress especially during the growing seasons for it reduces the number of tubers bulking and can inhibit future bulking, decreasing the potato grade in terms of tuber sizes, the quality and generally lowers the potato yields (Blom-Zandistra, 2015). The onset of long rains always determines the time of farm clearing, preparation and planting and if the onset of rainfall for each can be specified and certain, then the potato planting time can be determined to get the maximum yields (Adeniyi,2009).

Furthermore, Watson *et al* (2004) analyzed potato productivity in Bolivia and found that rainfall seasonal changes were a major problem affecting potato yields in that when the onset of rain delay and last for few months, it reduces the growing period. Watson *et al* (2004) further found that rainfall in Bolivia was delaying and rather than beginning in October, the rains were starting in December and would not last for long affecting production of Irish potatoes. However, Jovovic *et.al* (2013) contrasted that potato is a plant of temperate climate which, due to strong polymorphism, quite easily adapts to different environmental conditions and as a result, this culture is now grown in almost all conditions, even at high altitudes, where the cultivation of other field crops was not possible. The Authors however indicated that, in recent years potato production is becoming more sensitive to various types of natural hazards including climate change and loss of habitat which are the greatest threats to the survival of wild species of potatoes where 13 wild species and about 52% of natural habitats could permanently be lost by 2050.

In their later study, Jovovic *et.al* (2016), maintains that the decrease in potato yield can be affected even by short periods of drought, especially if they occur in the early stages of the formation of tubers. At this stage, drought favours the emergence and development of common scab while the later stages favour occurrence and attack of potato tuber moth, which arrives to the tubers through the cracks in the soil. In addition to the drought, the extent of common potato scab is significantly affected by the increased acidity of the soil.

Elsewhere in South Africa, Franke *et.al* (2013) found that potato farmers currently grows very limited range of varieties and 60% of the tables potatoes are supplied by a single variety which is highly affected by drought. For instance, in Limpopo, yields were highly irregular in the first 50 years assessed.

In Kenya, the erratic pattern of rainfall causes increased cost of production to some of the farmers who normally plant their crops during dry season just before the onset of the rains. According to Mbaisi, (2014) this practice is only beneficial if the rains are consistent but in the event that the rains are not consistent and timely there is usually poor germination and poor emergency that may lead to re-roughing and replanting which increases the cost of production and lowers the gross margin for farmers. Water and nutrient availability are the main factors that generally determine potato yields. However, irregular rainfall patterns result in high risk of drought and intra-seasonal dry spell, leading to low crop yields and sometimes total crop failure (Kinoti et al., 2010). The potato farmers continue to use rain-fed agriculture in the traditional potato growing areas, which is largely dependent on the rainy seasons. Inadequate modern appropriate technologies in production, wide spread pests and diseases contribute to low production while inadequate and inappropriate storage facilities make the farmers to sell their produce immediately after harvest to avoid high postharvest loses. Most potato farmers still practice subsistence farming and have not embraced commercial farming. Lack of agribusiness management skills, inaccessible and unaffordable credit facilities, poor marketing systems, poor rural access roads and inadequate land all hinder commercialization of potato production.

In a study carried in Oljoro-orok, Karanja (2013), found that the potato yield dynamics is as a result of variation of rainfall and different soil types. Giving example; the author found that when rainfall is high, the lower zones of the region is affected by water logging and when rainfall are low the upper zones record low yield since the black cotton soils drain very fast while in lower zone potato yields increase during such a time because the soils retain water. The author also indicated that rainfall variation and lack of clean seeds are the main challenges to potato farming and since rainfall is the only source of water to Irish potatoes in the division, it means that the variation of rainfall leads to variations in Irish potato yields. The study further found that the division is endowed with resources which when well utilized will be a great opportunity to potato farmers in Oljoro-orok division.

Further, MoALF (2016) report shows that, Irish potato value chain is affected by both drought and intense rain which become even more intense as the weather become increasingly unpredictable. The rains come when they are least expected, while dry spells are abnormally long and more frequent, adversely affecting all the actors along this value chain with producers (farmers who cannot adapt to the harsh weather events due to limitations in resources and knowledge) receiving low returns from production, workers doing land preparation and weeding under unfavourable conditions receiving lower wages while transporters and bulkers lose their jobs. The report also pointed that actors in potato growing areas that are more prone to droughts and floods such as Ndaragwa are the most affected (MoALF, 2016).

According to Ministry of Agriculture (2007) increase in potato production occurs simultaneously with increase in production of cereals and other staple crops and the changes in growing seasonal precipitation by one standard deviation can be associated with as much as 10% change in production. In Kenya, there is an already persistent food problem as a result of low yields which has led to conflicts among communities due to water shortage Lobell *et.al* (2008).

2.3.2 Impacts of Temperatures on Irish Potato production

Potato yields have decreased in many regions especially in the tropics because of increase in temperatures, and since all potato varieties do well in cool climate between 15^{o}C to 18^{o}C, if temperature rises beyond 20^{o}C it shortens the growing period and reduces the yields (Hijman, 2003). According to Muthoni *et al* (2015), high temperatures due to climate change led to low yields resulting from increased developmental rates and high respiration that cause short growth cycle resulting to low yields, because potatoes will only have short time to accumulate photo assimilates that help in bulking. Most Irish potato varieties do well at an average daily temperature of 14^{0}C to 20^{0}C but beyond that high temperature leads to rapid yield decline. The study for example observed that variety Desiree yielded 0% while variety spunta yields reduced to 15% at the temperatures of 27^{0}C (Hancock, *et al* 2013).

Temperature pattern also influenced potato in tuberization stage which in turn reduces crop production and quality (Borah, *et al.,* 1962; Muthoni, *et al,* 2015), observed that at lower temperature of 15^{0}C tuberization was delayed by one week and at higher temperatures of 25^{0}C tuberization was delayed by three weeks which they associated with slowed metabolism and growth at low temperatures and inhibitory effects of the higher temperature during tuberization processes. However, Info Resources (2008) shows that overnight temperature has a crucial influence on starch deposit in potato tubers with tuberization depending largely on the night minimum night temperatures of 15 to 18^{0}C but beyond 20^{0}C tuberization is reduced and at 25^{0}C tuberization does not take place at all. According to Blom-zandstra *et al* (2015) high temperatures promote foliar development, delay tuberization and influence potato quality characteristics such as producing higher numbers of smaller tubers per plant.

Another effect of temperature on Irish potato production that has been reported is the increase in potato height with reduced tuber. Wolf *et al* (1990) reported that at high temperatures during the long day favours the assimilate partitioning to the above ground vegetative parts and as a result above ground biomass and plant height increases while tuber yield below reduces because assimilated carbon is partitoned to tuber at night by the minimum temperatures.

In a later study, Modisane (2007) observed that high temperature of $27/17^{0}C$ had a more detrimental effects on vegetative growth than tuber growth. Using experimental study, she exposed different potato seeds to high and low temperatures and observed that at high temperatures of $27/17^{0}C$ the Irish potato had high leaf area, tall stem and high leaf dry mass compared to potato exposed to lower temperatures at $22/14^{0}C$, while tuber dry mass and total dry mass were favoured by lowering the temperatures to $22/14^{0}C$ meaning that at high temperatures the potato/plant length increases while tuber bulking and stolon formation remains low. She also observed that at lower temperatures tuber yields were higher compared to that of high temperatures. Nagarajan, *et al;* (1995) and Muthoni, *et al*, (2015), further point out that high temperatures lead to development of tall potato crops with thin stems, small leaves, long stolons, increased numbers of inter-nodes, elongated internodes and inhibits tuber development by decreasing the ratio tuber fresh weight which generally reduce the crop yields.

In contrary, Nonhebell (1993) in a study in Netherlands points out that global warming could lead to beneficial lengthening of growing season and temperature may rise to optimal for potato production while the increase of atmospheric carbon dioxide (CO_2)

concentration will likely increase crop yields especially when water shortage limit crop production, The author also indicates that potentially, the growing season is longest in this period, relative to the later years, as heat stress in autumn and spring is less frequent. He further says that although Frost in winter have regularly damaged the crop in the first 50 years occasionally leading to minimal yields, yields are becoming more stable as frost incidences reduce and eventually disappear.This corresponded with a later study in Limpopo where Franke *et al* (2013), found that Irish potato production are somewhat unexpected by farmers because frost bite occasionally interrupt the crop in the early years, leading to very low yields for it occurs soon after full ground cover is reached. However, the author found that average yields do not change much in Limpopo, which is making sense given that there is a long growing season and the disappearance of frost risk is becoming a major advantage of climate change for the potato growers.

Further, Linus F. *et al*. (2014) says that the increase in temperatures (especially in early spring) is generally expected to benefit potato production in this region, as the suitable period during which potato can be grown without substantial risk of frost is expected to lengthen considerably over time. The cold winter period (unsuitable for potato production) will become shorter by some 50 days between now and 2050 and as a result farmer will be able to start planting earlier and/or harvest later. They reported that potato producers in the Eastern Free State region can reap the benefits of increased CO_2 levels and increasing photosynthetic rate through higher expected yields and lower water requirements by the crop. However, FAO (2005) reports show that, despite the warming up of the earth, frost will continue to be experienced globally. The report further indicated that frost is among the leading weather hazards that substantially reduce production of vegetables, pasture and even forest cover. Giving an example, the report shows that in the United States of America, the major economic losses are caused by poor crop harvest due to freezing of crops before maturing.

In Kenya high temperature and high carbon dioxide concentration will lead to increased crop yield. Nyongesa *et al*. (2008) examined the tolerance of potato with changes in temperature and they found that in Kenya there are varieties of potatoes that have previously been doing well in certain regions despite the increasing trends of temperatures. However, Nyakundi *et al* (1991), warns that although carbon dioxide will increase crop yields, it will at the same time boost growth of weeds and considering farmers in Kenya operate at low imputes levels, crop yields may drop because in areas that receives low rainfall which may not sustain crop germinations, weeds will rapidly grow in the early seasons utilizing much of the soil water and nutrients reducing soil fertility increasing the cost of production.

Just like in other places, frost is commonly experienced in Kenya especially in areas across the Abardares and Mt. Kenya regions damaging crop at any development stages with severe damages occurring during flowering and fruits development stage affecting the health of plants by damaging their leaves, fruits, flowers and eventually causing death of plants (Monica, 2013).

In a later study, FAO (2015) recorded that Kenya Tea Development Authority (KTDA) posted a 1 billion loss in 2012 due to frost bite that damaged tea plantations in Central and Rift valley. Kotikot and Onywere, (2015) in applying GIS and Remote sensing techniques in frost risk regions of Central Kenya also found that frost affects livestock for it causes severe shortage of pasture and fodder leading to death of animals. The study further indicated that frost affects all kinds of plants including grass and that the damage is aggrevated by lack of adequate information on frost. This calls for studies geared at assessing the impact of climate change related risks. The current study was therefore designed to establish a clear link between climatic risk including frost and potato yields and increasing the insight by looking at the impact of climate change on Irish potato production in Ndaragwa agro-ecological zone because the previous studies have focused on other crop varieties and livestock in general ignoring Irish potato production which is an important crop in the area.

Apart from the direct effects, high temperatures combined with high rainfall are associated with the increasing incidences of pest and diseases which is one of the main causes of potato decrease. Naintoh *et al* (2018) reported that 63% of interviewed farmers stated that potato bright and rot were caused by increase in both rainfall and temperatures. In a similar study Sophie (2018) reported that 64% of Shangi variety growers in Kenya had already experienced losses due to increased number of pest and diseases. In another study Olanya *et al* (2006) reported that late blight is becoming the most common disease that affects potato production especially during high rainfall because floods increase the spread and infection of potato bacterial diseases from infected plants or soils. A guide to Irish potato production by Kenya Horticulture Competitiveness projects (KHCP, 2013) shows that most of the Irish potatoes pest and diseases thrive well in warm and humid environment for example, potato bright, black scurf and bacterial wilt diseases spread out in cool humid weather through infected tubers and causes big economic losses during long rain seasons, while Aphids, potato tuber moth, cut warms and nematodes are becoming more common especially in warm, dry and high altitude areas where their effects have already been felt by potato farmers reducing most of their production..

Lastly, Hijmans (2003) says that future potato yields could decrease in many regions because of increases in temperature. However, the author says that in some regions, mainly in temperate regions, yields decline can partly be avoided through practicing adaptation strategies that will increase yields at high latitudes because of a lengthening of the growing season. The author further points out that in practice some of these "autonomous" types of adaptation may not be that straight forward because the planting season of a crop also depends on other factors like other crops (particularly in production systems with multiple cropping), water availability, pests and diseases, and markets. Moreover, potato varieties with a maturity that is better adapted to a changed climate may exist, but are perhaps not available to farmers in a specific region, or they may not have good market value. Many potato varieties are photoperiod sensitive, but adaptation might decrease the temperature sensitivity of their development rate incase better technology are used which will only be embraced by farmers when the accurate information is provided. Although the scientific perspectives mitigation and adaptation strategies have been documented, little exists on the farmers understanding (Obidiegwo *et al* 2015). The current study aimed at contributing knowledge on farmers understanding of climate change risks on Irish potato production.

2.4 Coping Mechanisms to Mitigate Impacts of Climate Change and Variability on Small-Scale Irish Potato Production

2.4.1 Building Resilience & Resistance to Climate Change and variability

Blom-Zandstra *et.al* (2015) analyzed potato production systems in different agro ecological regions and their relation with climate change in Netherland. The study used resilience theory and found out that climate change is a key issue which has the potential to change the production and processing landscape. The study suggests that potato production systems will have to respond to the impacts of climate change through irrigation practices, soil coverage by mulching, intercropping or mixed cropping and possible integration with aquaculture.

According to Allen *et al* (2005), the main objective of adaptation is to develop positive attitudes and resilience for people to believe in their capacity to face both the challenges and opportunities presented by climate change and variability. They established that Impacts of climate change can only be reduced when the society embraces flexibility and builds resilience towards a wider range of potential effects of climate change and that farmers should be able to adapt in order to reduce the negative impacts of climate change and variability. The authors further say that Adaptation to climate change is a two-step process which requires that farmers perceive climate change and variability in the first step and respond to changes in the second step through adaptation. However, they found that different socio-economic and environmental factors affect the abilities of farmers to perceive and adapt to climate change.

Elsewhere in Austria, Darnhofer *et al* (2008) say that developing resilience to climate change and variability entails actions that people undertake either individually or collectively; building resilience requires one to take measures that will enable the natural systems and community to cope with extreme weather events. They further point out that potato farmers require a combination of adaptation and mitigation measures generally by being prepared for these unpredictable weather conditions and to desire to survive by making better choices of potato practices by understanding climate science through agricultural officers.

Kabubo *etal*. (2015), point out that the government can also play a bigger role by ensuring policy-driven adaptation to climate change, especially in more vulnerable counties. They say that though farmers may be aware of the effects of climate change, they may not always have full information about adaptation options available to them. Continuous climate change monitoring, intensified early warning systems and dissemination of relevant information to farmers are crucial, even where farmers have information. The author however indicates that farmers may not have the means to adapt to the suggested adaptation options although they may be important for very vulnerable farm households who have the least capacity to produce food.

Several studies have recommended changing times of planting or sowing. For instance, Franke *et.al*. (2013) argues that growers should try to avoid too hot conditions in summer due to its negative repercussions for emergence and tuber quality, as well as the high water needs during summer with declining water levels. In addition, the niche winter crop yields the highest prices on the markets because most regions do not deliver potatoes to the market. The authors point out that the best months to plant Potatoes by 2050 will be in the period April- May, with a strong yield increase from 49 to 77 ton per ha-1 (+57 %). This increase is not only due to higher CO_2 levels and more optimal temperatures for photosynthesis, but also due to a reduction in the risk of frost damage and with time, the period of highest production will also coincide with the preferred operational and market requirements.

Patt *et al*. (2005) points out that climate change impacts on rural farming communities can be reduced by distributing climate data regarding seasonal climate forecasts based on short-term and long-term. Forecasts to small-scale farmers help them make more informed farming decisions and adapt to the changing climate conditions. However, some farmers have already started to use this information and are preparing themselves for dry conditions by planting drought-tolerant potato crop.

Other measures to cope with climate change on potato production include changing the potato variety, to plant a more tolerant species that can adapt to the extreme weather conditions and diversify from traditional potato crop to other types of crops such as cassava and millet to change peoples' livelihoods and improve on food security

(Skambraks, 2014). She also indicates that, rain-fed agriculture is different from irrigated systems in capital base to crop production and is therefore the main economic activities that most of the rural farmers can afford and depend upon. In the context of nation's food security and eradication of poverty therefore, the government should focus and enhance productivity of rain-fed agriculture by restructuring the agricultural policy and embracing the improved farming technologies that are focusing on optimizing water-use efficiency by improving irrigation facilities, to bring more land under irrigated potato production and saving many litres of water to save the situation.

According to a study carried out in South Africa, Zambia and Zimbabwe, Nhemachena *et.al* (2007) indicated that using different crop varieties, crop diversification, changing planting dates, switching from farm to non-farm activities, increased use of irrigation, and increased water and soil conservation techniques were the different adaptation measures employed by farmers in these countries. The study also reported that most farmers perceived long-term increase in temperature and that the region was getting drier, with changes in the timing of rains and frequency of droughts. The farmers reported that lack of credit facilities and information on adaptation options and insufficient inputs are the main barriers to adopting any climate change adaptation options. The results of the multivariate discrete choice analysis show that gender, years of farming experience, access to extension services, access to credit facilities and markets are the significant determinants of adaptations to climate change in the region

In a later study in South Africa, Gbetibouo (2009) observed that even though a large number of farmers interviewed noticed changes in climate, almost two-thirds chose not to undertake any remedial action. He adds that among those farmers who did adapt, common responses included planting different crops, changing crop varieties, changing planting dates, increasing irrigation, diversifying crops, changing the amount of land grazed or under cultivation, and supplementing livestock feed. While adopting a new crop variety was the main strategy used to adapt to increasing temperature, building water-harvesting schemes was a popular strategy for coping with decreased precipitation. The study also indicated that farmers cited a number of barriers to adaptation including poverty, lack of access to credit and lack of savings. Insecure property rights and lack of markets were also cited as significant barriers to adaptation. A few farmers also reported lack of information and knowledge of appropriate adaptation measures as barriers to adaptation.

Adger *et al*. (2007) and FAO (2007) indicate that adaptation to current climate variability can also increase resilience to long-term climate change. In a number of cases, however, anthropogenic climate change is likely to also require forward-looking investment and planning responses that go beyond short-term responses to current climate variability. They added that, even when effects of climate change are not yet discernible, scenarios of future effects may already be of sufficient concern to justify building some adaptation responses into planning. In some cases, it could be more cost-effective to implement adaptation measures early, particularly infrastructure with long economic life.

In Ethiopia, a study carried out by Yesuf *et al*. (2008) reveal that changing crop variety, soil and water conservation, water harvesting, planting of trees and changing planting and harvesting dates are the choices of adaptation measures adopted by the farmers. Among these methods of adaptation, planting trees was the measure adopted by most farmers. However, about 42% of the farmers did not use any adaptation method for climate change impacts. The study also showed that household wealth represented by farm and non-farm income and livestock ownership, increases the likelihood of climate change awareness and adaptation.

In Kenya, Ngigi, (2009), says that agricultural water management is one of the best ways for agricultural activities to adapt to climate change and variability. Water management can be improved through a diversity of options such as shallow wells, boreholes and rainwater storage. Nonetheless, he says that the ecological and socio-economic effects of these options need to be investigated.

According to Jokastah *et.al*. (2013), in their study carried out in semi-arid and sub-humid regions in Kenya, found out that, even if it rained in the morning hours in the region, by the evening the soil looked dry due to hot sun and high temperatures. However, farmers in these areas had counteracted such events by use of mulching, manure and changing to crops that are drought resistant as well as the early maturing maize varieties such as KDV2 and KDV4. The authors also reported that farmers however lamented that despite sorghum and millet being among the recommended drought resistant crops; it was not commonly planted because their children did not enjoy eating them and insisted on maize related meal like Ugali and Porridge.

Elsewhere in Oljoro-orok, Karanja (2013) established that farmers have been able to adapt to rainfall variability through irrigation, timely planting, off season approach where they leave a portion of the land bear to replenish during unfavorable rainfall seasons and crop diversification where they plant other crops such as animal feeds and vegetables such as cabbages, onions and carrots that matures faster in times of unfavorable rainfall.

Samuel (2016) in his study in Kijabe found that farmers were applying various adaptation strategies to the effects of climate change and variability. These include; mixed crop farming, growing fast maturing crops, planting drought resistant crops, rain water harvesting and irrigation agriculture. The author found that education level, access to weather information, water availability, rainfall and temperature were vital determinants of farmers' adaptation to climate variability. However, the study also identified some challenges to climate adaptation strategies among the farmers in Kijabe which included ; lack of improved seeds (87%), lack of capital (86%), poverty (81%), lack of necessary farm inputs (77%), poor transportation (76%), poor infrastructure (73%), lack of information about proper adaptation mechanisms (69%), lack of ready market for farm produce (61%), lack of timely climate forecasting information on the expected climate changes (53%) and shortage of water for irrigation (52%). The study recommends that rain-fed farming in Kijabe needs to be complimented with drip irrigation, rain water harvesting (this includes roof water and floodwater collection) and green house techniques to enhance sustainable crop production. The author further recommends that water catchment areas that act as sources of most rivers in Kijabe should be rehabilitated with indigenous trees e.g. bamboo. This is because scientists predict increased impact of climate variability on ecosystems in sub-Saharan Africa, which is expected to have serious socio-economic and environmental effects on farmers whose livelihoods depend on rain-fed farming.

In Kenya, the first national policy document to fully acknowledge the reality of climate change was the National Climate Change Response Strategy (2010) which has been guiding policy decisions since its launch in 2010. The Strategy provided evidence of climate impacts on different economic sectors and proposed various adaptation and mitigation strategies.

The Government of Kenya earlier came up with many policies and institutions that are expected to build resilience and mitigate climate change and variability. Some of these include: Kenya Vision 2030 Blueprint, which was launched in 2008 as the country's long-term development blueprint replacing the Economic Recovery Strategy (ERS) for

Employment and Wealth Creation blueprint of 2003. Kenya Vision 2030 identifies agriculture as a key sector through which increased economic growth rates can be achieved. Under the Vision, smallholder agriculture is to be transformed from subsistence activities, marked by low productivity and lack of value addition, to 'an innovative, commercially-oriented, internationally competitive and modern agricultural sector' (FAO, 2015 pp.).

The other one is the National Climate Change Response Strategy which highlights various measures for adapting agriculture to climate change and for mitigating the emissions of greenhouse gases in agriculture. Some of the strategies proposed include adoption of a range of innovative methodologies, processes and adaptive agricultural technologies from analogue environments, crop diversification, mixed cropping, tree planting, irrigation and diversification of livelihoods, enhancing early warning systems with drought monitoring and seasonal forecasts (GOK, 2010b).

The Kenyan Constitution of (2010) also provides ground for the formulation of adaptation and mitigation legislation, policies and strategies by guaranteeing the right to a clean and healthy environment under the Bill of Rights (GOK, 2013).

Lastly, the Draft National Climate Change Framework Policy 2014, which is the latest in a series of national climate policy blueprints, provides for policy statements to enhance climate resilience and adaptive capacity; to promote low carbon growth; and to mainstream climate change into planning processes among others and to develop incentives to promote climate resilient actions through appropriate policy reforms (FAO, 2015).

According to NCCAP (2013), the Government of Kenya has been addressing climate change impacts, especially drought, for many years. These interventions have been geared towards disaster risk reduction, humanitarian action, preparedness and response actions, including efforts of the National Drought Management Authority (NDMA) to address drought and through the department of Special Programmes, for floods and other disasters. However, as climate change risks and their effects increase, additional efforts will be required to address future impacts and enhance sustainable development to enable the country to attain its goals under Vision 2030. Although many studies have been carried out on adaptation strategies, there is little research on how Irish potato farmers are adapting to the effect of climate change in Kenya. Furthermore, the Kenyan policies are generally on climate change and agriculture at large without considering specific crops. The current study focuses on the effect of climate change on potato production and recommend on strategies to be adopted by potato farmers that can be incorporated in our policies.

2.5 Theoretical Framework

The theoretical model that guided this study is **Resilience theory**. The concept of "resilience" was first mentioned by Tredgold in 1818, and later gained its popularity in 1973's and 2006 through the work of Gunderson and Holling 2002, Holling 1973, Walker Salt 2006, Folke 2006 among others. Holling, (1973.) defines resilience as the amount of change a system can undergo and still retain the same basic function. It is the degree to which a system is capable of self-organization, and the degree to which a system can build and increase its capacity for learning and adaptation (Folke 2006).

Gunderson and Holling (2002) compared and contrasted the concept of resilience with the notion of stability, which they defined as the ability of a system to return to its equilibrium state after a temporary disturbance; that is the more rapidly the system returns to its equilibrium, the more stable it is. They concluded that resilience and stability are two important properties of an ecological system because the concept of resilience provides a new and useful framework of analysis and understanding on how individuals, communities, organizations and ecosystems cope in a changing world facing many uncertainties and challenges. Nelson (2007) defines resilience theory as the amount of disturbance that an ecosystem could withstand without changing self-organized processes and structures and was conceptualized in close relationship with adaptation to the environmental change.

Further, Välikangas *et. al* (2003) in their study suggested seven characteristics of theory that include: threat or risk and events, positive/possible outcomes, being prepared, desire/commitment to survive, adaptability, gaining experience, and Collective and coordinated response. They also pointed out that at the very beginning of the twenty-first century the resilience theory in ecology was enriched by the detection of its close links with the concept of adaptive capacity, which in socio-ecological systems refers to the ability of humans to deal with change in their environment by observation, learning and altering their interactions. This study will focus on these characteristics to assess the impact of climate change and how community can adapt to the changes.

According to Olena (2016) and Forlke (2006), the understanding of resilience theory has led to spread of the climatic resilience concept, which is generally defined as the capacity for a socio-ecological system to: "(1) absorb stresses and maintain function in the face of external stresses imposed upon it by climate change and (2) adapt, reorganize, and evolve into more desirable configurations that improve the sustainability of the system, leaving it better prepared for future climate change impacts.

Ramasamy (2012) analyzed Climate risk and management on agriculture in Columbia using resilience theory. In the study, the author concluded that agriculture sector is highly exposed to climate risks and that majority of risks associated with production are because of adverse climatic conditions and inherent climate variability representing treat to farmers. The author also says that climate risks are often translated into poor crop yields and sub-optimal performance of livestock enterprises and they are capable of altering other risks such as asset depletion (damage and loss to assets as a result of extreme climate events), price risks (risk of falling or raising prices) and financial risk all related to the effects of climate change.

Elsewhere in Sahel, A. Ickowicz *et, al* (2012) says that enhancing resilience of crop and livestock systems means to increase the capacities of farmers to adapt to different types of shocks associated to: climate, economic, sanitary and related issues to land and demographic pressure that have been part of their life for decades. In their analysis, they found out a number of strategies and securization systems among them mobility, diversification of activities and incomes, food security, intensification, collective management, share of resource among others that involve not only their own capacities, ideas and skills but also the resources (biophysical, human, institutional, economic, etc.) present in their environment at different spatial scales (village, rural community, regional or national).

In Australia, Muller (2017) found that while a collaborative approach to risk governance is emerging in some cases, there are significant constraints to cultivating climate change resilience in fresh produce supply chains in Australia – and that this adds to known threats to our national food security. The study adapted resilience theory suggested that adopting a risk governance perspective could help to engage a wider set of social actors, particularly governments and consumers, in the process of improving supply chain and food system resilience in the face of climate change.

In an earlier study in Africa Dixon *et.al* (2015) found that smallholder farmers often have significant expertise when it comes to managing their farm system. The study used resilience theory and recommended that there is potential to learn from farmers and where possible, their experience and knowledge should be integrated and enhanced to strengthen the resilience of farming systems. They also argued that contextually-relevant information and locally-identified indicators provide a practical way to monitor progress and also increase the potential of generating contextually relevant solutions that can not only increase resilience but also empower farmers in the process of coping with climate change risks.

In Kenya, Omolo *et, al* (2017) investigated on gender and resilience to climate variability in pastoralists livelihoods system in Turkana and in their analysis, the authors used the resilience concept and their results reveal that pastoralists are less resilient and vulnerable to climate change because of inequalities in accessing basic assets, lack of information, illiteracy and poverty. Although the current study used the same approach as the resilience studies, it differs in that it analyzes how climate change affects individual crop, Irish potato, while the rest of the studies either focused on the impact either at whole agricultural sector, the crop agriculture sector or the livestock sector.

Following the above backdrop, the study applies resilience theory to analyze the impact of climate change and variability on small scale Irish potato production which is already termed as an event and a threat that requires every stakeholder to be prepared and have the ability to absorb and recover from extreme weather changes and variability. The theory is also relevant to the study because the main focus discussed in the theory is to understand different participatory processes and the co-production of knowledge. The theory emphasizes that responses require active participation from governments, citizens, scientists, and private sector to build resilience to climate change and variability. It is therefore possible to say that today; resilience theory emphasizes ideas of management, integration, and utilization of change to catalyze the evolution in the social ecological system under study rather than simply describing reactions to change, (Olena, 2016). In addition, Folke *et al*., (2010), indicates that it is evident that increasing resilience can be realized by reducing vulnerabilities and increasing adaptive capacity. Resilience can be achieved for every specific risk by reducing sensitivity, exposure and increasing adaptive capacity. These measures can be achieved by intervening into all different dimensions namely: biophysical, economic and social. Building resilience can only be achieved when every stakeholder is involved and this is only through creating awareness of the serious threat of climate change on each crop variety which means that more studies should be carried out basing on different crops.

2.6 Conceptual Framework

Taking into account the above theory, climate change and variability is the (independent variable) and poses great threat on Irish potato production (dependent variable) in Ndaragwa Agro-ecological zone through the increase and decrease in temperatures, erratic rainfall, floods, prolonged rainfall, prolonged drought and extreme weather events. This varying and changing of climatic events have impacts on irish potato crop production through expansion of aridity into agricultural productive land and changing people's livelihoods, increase of pest and diseases, increasing cost of production as a result of re-ploughing and replanting incase of crop failure, use of pesticides to prevent pest and disease damage; soil degradation, immature Irish potato crop harvest to save them from frost bites and reduction of crop production, hence food insecurity and high rate of poverty.

This therefore calls for building resilience where demographic factors, political factors, poverty, fragile ecosystem, policies, local knowledge and capability are important factors to consider as (intervening variables) which either intensifies the effect of climate change and variability in either direction. In building resilience, there is need for mitigation, an effort of reducing the adverse effect of climate change and variability by minimizing GHG emittion to the atmosphere and adaptation which is adjusting to counteract the currect and the expected effects.

Different characteristics of resilience building like gaining experience, being prepared, adaptability, collecting and coordinated response to enhance household adaptive capacity most definitely will have fruit bearing on what to happen environmentally, economically and socially both at present and in the future. The general well-being of the society (farmers) will depend on how effective the adaptation strategies are executed. If done sustainably then chances are that the needs of Ndaragwa community will be catered for at the moment and not jeopardizing that of the future generations.

The conceptual framework therefore portrays the linkage between climate variables (independent variable) with livelihood outcomes such as rainfed Irish potato production (depedent variable), intervening variables and ways of building resilence in the face of climate change and variability. It shows how climate variability and change directly influence agriculture and specifically Irish Potatoes, a sector that relies more on precipitation and temperature, which in turn affect food security and influence social, environmental and economic factors. The framework illustrates how policies and institutions directly influence planned adaptation to impacts of climate change and the affected community. Planned adaptation reduces vulnerability of households and builds resilience to climate extremes through the adoption of climate-smart agricultural technologies.

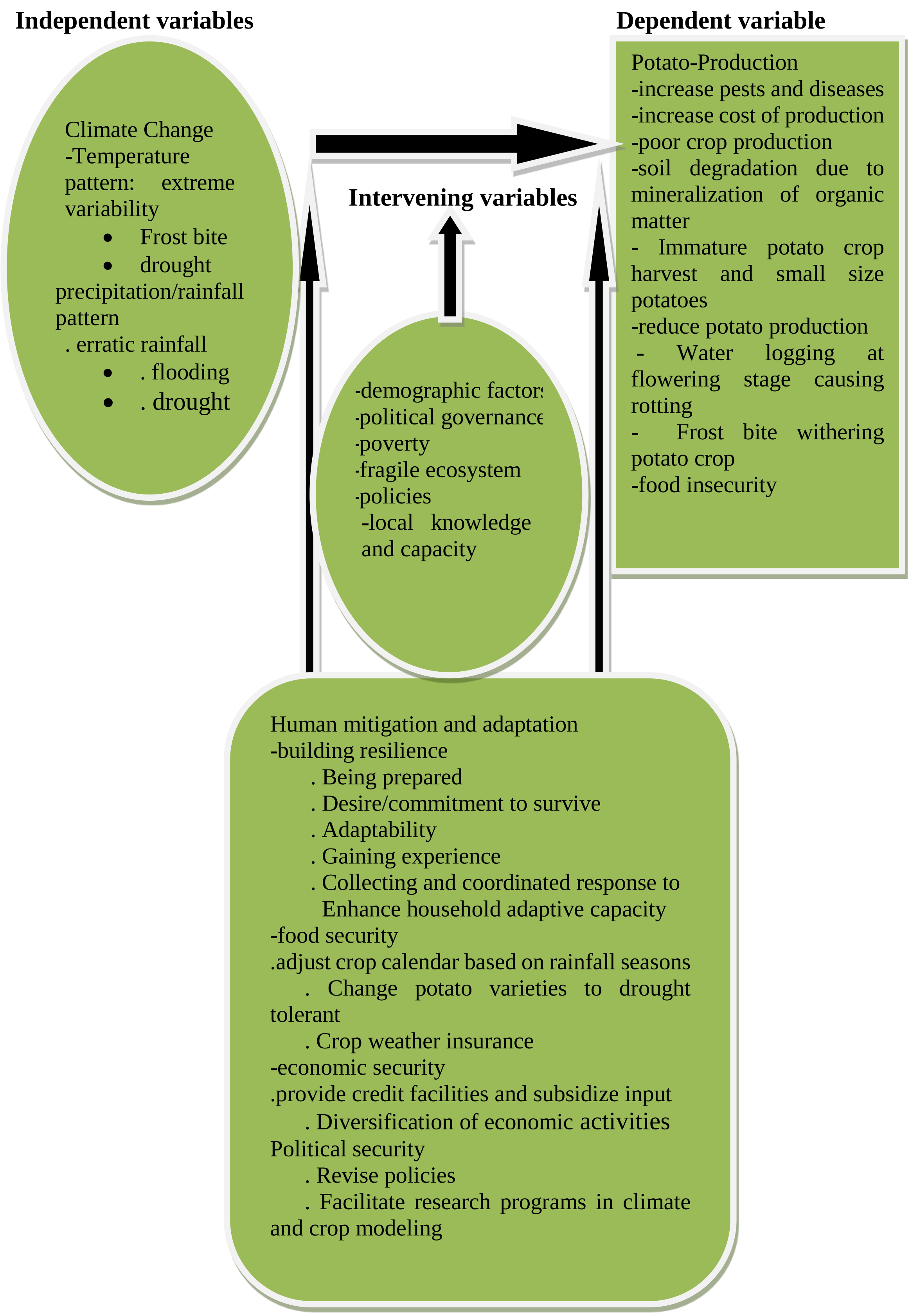


Figure 1.2: Conceptual Framework

Source: Author, 2019 Synthesized from Literature Review and theoretical Framework

2.7 Summary

From the literature reviews, it is evident that climate change is real and is happening affecting almost every sector including; social, economic and environmental. However, the literature reveals that agriculture is the most affected sector because it entirely depends on climatic elements for its survival. Despite these high consequences related to climate change, there is lack of sufficient information on how different crop varieties and different locations are affected differently and the best mechanism that should be applied by different farming systems. This necessitated a change of focus to narrow down to specific crop variety Irish Potato and localities. From the literature review, small scale farmers in most arid and semi-arid regions are mostly neglected and the focus is on pastoralists yet they are also influenced by climate change and variability. Most climate change studies focus on climate parameter rainfall and increasing incidences of temperatures ignoring falling of temperatures, which is a major challenge in the current study area and finally, to build resilient on effects of climate change and variety a combined effort from all the stakeholders is very vital rather that individual or farmers efforts. It is therefore the following knowledge gaps that necessitated the current study to fill in the gaps.

CHAPTER THREE

METHODOLOGY

3.0 Introduction

The scientific research requires different methods, techniques and tools to obtain data. Research methods entail the general research techniques or framework which determines the kind of data the researcher obtains. The research methodology describes the plan and tools that was used in the field. The research tools include interview guide, questionnaires, maps, photos, computers, and library search by reviewing journal articles and books among others. This chapter therefore covers research methodology in terms of the research design used in this study, target population, sampling procedure and sample size, data collection, procedure used to carry out the pilot study or pre test before doing the actual data collection, actual data procedure used in this study, research instruments, how reliability and validity was attained for the research and methods used and data analysis and data presentation.

3.1 Research Design

A design is a logical model of proof that allows the researcher to draw inferences concerning causal relationships among variables under investigation. Since the study was set out to examine the effects of climate change on potato production in Ndaragwa region, a cross-sectional survey research design was adopted in this study. It involves using different groups of people who facilitated the collection of wide range of data on various variables such as change of climate and Irish potato production. The research design also enabled the researcher to analyse the perception of people on the effect of climate change on Irish potato production as well as establishing the adaptation strategies used by the local people to counteract the effect of climate change. The research design allows for description and test of relationships of phenomena. The strength of the design lies in its flexibility which easily allows different aspects of the problem to be considered and enable the exploration of the opinions, attitudes and behaviours of the communities at risk, government officials and people working in farms and are either affected directly or indirectly by climate change and variability in the study area.

The cross-section survey has been used severally in different studies among them Mendelsohn *et.al* (1999), on the impacts of climate change on agriculture in developing countries where the design enabled the collection of data that revealed that local people in rural areas could be heavily affected by climate change even in circumstances when the aggregate agricultural sector in the country does well compared to other sectors.

In another study in Asia, Lee *et.al* (2012) used cross-section design to analyse impact of climate change on agricultural production. The design allowed for successful collection of data that shows that although Asian countries are the major rice producers in the world, climate change will negatively continue to affect rice production and consequently, price of rice will increase to an extent that less fortunate people will not afford.

In Kenya, Karanja (2013) analyzed rainfall variability on Irish potato production in Ol-joro-orok division, Nyandarua County using a cross-sectional design and found that variability of rainfall leads to variation of potato, as rainfall is the main source of water for potato growth. Elsewhere, Okaka (2016) used a cross-sectional design to study urban resident's perception and adaptation capacity to the health risks of climate change in Mombasa and found that participants had a clear perception of health risk of climate change and supported calls for framing climate change from a health perspective to motivate behavior change to protect the public from the negative health consequences of climate change and finally, Kimani (2017) used cross-section design to study the climate change impact on maize production in Kitale and Eldoret and was able to obtain robust data that showed that the net farm revenue is more responsive to variation in temperature than changes in precipitation because a change per unit temperature has a much far reaching effect than a unit change in precipitation. The successful use of cross-sectional survey in the study, thus informed its preference.

3.2 Target Population

According to Mugenda and Mugenda (2003) population is the entire group of individuals having a common observable characteristic. The study targeted all the small-scale households' heads growing Irish potatoes that are rain-fed in Ndaragwa and have stayed in the region for more than five consecutive years. This is because they were expected to explain the changes, they have observed in climate over five to ten years and whether the changes affected the production of Irish potatoes.

3.2.1 Sampling Procedures and Sample Size

Sampling was done by selecting a given number of subjects from a defined population as representative of that population. This therefore means that any statement made about the sample should be true of the population (Orodho, 2002) and that the larger the sample size, the smaller the sampling error (Gay, 1992). Different sampling techniques were used that included; Purposive sampling, multi-stage sampling, simple random sampling and stratified random sampling to identify the survey respondents from the study area. Multi-stage sampling which is a more complex form of cluster sampling that contains two or more stages in sample selection was first used. According to Mjuma, (2014) this sampling method is used in order to divide large clusters of population into smaller clusters in several stages in order to make primary data collection more manageable.

In Kenya Irish potatoes are grown in several counties including, Meru County, Embu county, Nyandarua county, Nakuru County, Narok County, Bomet county and Uasin Gishu county respectively. This marked the first stage from where Nyandarua County was purposively selected because the area is mostly affected by frost bite which is not commonly found in the other growing areas. The county has five sub-counties namely Kinangop, Kipipiri, Ol-Kalau, Oljoro-orok and Ndaragwa which are also categorized into seven agro-ecological zones (AEZs) namely: UH1 (North and South Kinangop), that receives relatively high rainfall, UH2 (North Kinangop) that falls in the high rainfall zone, UH3 (Olkalou, Kinganop), UH4 (Ojororok, Kipipiri), LH3 (Olkalou), LH4 (Ndaragwa, Kipipiri), in the dry ranching zone and LH5 (Ndaragwa) that is largely dry. These form the Second cluster from where zone LH5 (Ndaragwa) was purposively selected because due to climate change and variability, it is now considered a semi-arid region that experiences extreme climatic events since the year 1981 (MoALF, 2016). Despite such events, the region still produces Irish potatoes both for subsistence as well as for commercial purposes.

According to Mugenda and Mugenda (2003), purposive sampling is a sampling technique that allows a researcher to use cases that have the required information with respect to the study objectives. Further, Ndaragwa agro- ecological Zone has four administrative wards namely Leshau Pondo, Kiriita, Central and Shamata with a population of 98,396 and 27,917 households (KNBS, 2019). This forms the third cluster from where 398 households were determined using Yamane (1967:886) sample size calculation which is the same as using his table of sample size determination. The formula below was used to determine the sample size of 398 households.

$$n_0 = \frac{N}{1+N\,(e)^2}$$

Where n is the sample size

N is the population size (98,396)

e is the level of precision (5% i.e 0.05)

$$Hence, Sample\ Size\ (n) = \frac{98{,}326}{1 + 98{,}396\ (0.05)^2} = \frac{98{,}326}{1 + 98{,}326\ (0.0025)} = \frac{98{,}326}{1 + 245.99}$$

$$n = \frac{98{,}396}{246.99} = \mathbf{398.38051}$$

n=398 Households

After the sample size was determined, stratified random sampling technique was used to obtain the sub-locations within the four wards. According to Kombo *et al*, (2006) stratified random sampling is a technique that identifies subgroups in the population into separate homogeneous subsets that share similar characteristics so as to ensure equitable representation of the population in the sample. The list of all the sub-locations within the four wards were the sampling frame, where the researcher wrote them on small pieces of paper and put them separately into four groups representing the four wards and then picked two at random from each set. We decided on two sub-locations in each ward based on the available resources like finances, man power and time. Consideration of the two randomly picked areas led to selection of a total of 8 sub-locations as follows: shauri and Ndivai in Leshau pondo ward, Mairo inya and Karagoini in Kiriita ward, Simbara and Shamata in Shamata ward and Kanyagia and Muruai in Central ward.

The sample size per each sub-location was then computed based on the proportionate sampling or population equation 1, which is a technique where the sample size of each group/stratum is proportionate to the population size of that stratum in the target population (scheaffer *et al*, 2006). Basing on the list of the number of households and population density in each category availed from the office of the county Commissioner, Nyandarua County, the formula below computed sample size from even the smallest groups as seen in Table 3 below;

$$n = \frac{p}{\mu \ x \ S^n}$$

Where **n** –sample population of the division

P-population of the household in the location

μ-the total households in the division

$\mathbf{s^n}$- total sample size of the households in the division.

Table 3.1: Showing the Number of Households Sampled

AE ZONE LH5 (Ndaragwa)- wards	Sub-location	No. of H.H	No of HH per sub location
Leshau pondo	Shauri	3162	3162/27917x398=45
	Ndivai	2846	2846/27917x398=41
Kiriita	Mairo-inya	3451	3451/27917x398=49
	Karagoini	2830	2830/27917x398=41
Central	Kanyagia	4127	4127/27917x398=58
	Maruai	4609	4609/27917x398=66
Shamata	Simbara	3381	3381/27917x398=48
	Shamata	3511	3511/27917x398=50
Total		**27,917**	**398**

Systematic sampling method was used and it involved taking every k^{th} house as per the number of households in the sample sub-location on either side of the paths. The first household was selected randomly to obtain the starting points from the sub-chief offices and proceeded to pick every k^{th} number. In choosing the path ways was not a challenge because of the initial pilot study that was conducted to help the researcher appreciate and familiarize with topography of the area. The k^{th} variable was picked after every 35 houses and in cases where a household picked had not lived in the area for more than 5 years; the researcher proceeded to pick the next immediate one to obtain 398 targeted households. The household heads were the basic unit of the study and in cases where the household heads were not present at the time of administering the questionnaire, the oldest person from the same house was selected for the survey. Out of the 398 questionnaires that were administered 16 of them declined to take part in the study reducing the number to 382 properly completed questionnaires which were used for analysis. The responded questionnaires represented 96.07% return rate which exceeds the recommended 80% by Mmaduakonam (1998) and Okaka (2016).

The researcher together with trained research assistants also collected qualitative data from five Focus group discussions (FGDs) with between 10 to 15 participants both female and males and 10 key informants through the use of an open-ended interview guide that included the same issues and items on climate change used in the survey. The participants in the FGDs were basically farmers in field business schools which are groups of farmers that jointly work together with the agricultural extension officers in production of Irish potatoes in each sub-location. The researcher was introduced to five different groups namely: Kisha, Githungushu, Marwai, Ziwani and Mugiko farmer's Field Business School by the responsible officer per the region.

The ten Key informants were purposively selected. The researcher identified four farmers from those who had participated in the survey based on the analysis of their responses. The researcher also interviewed four agricultural extension officers who added in-depth information about effects of climate change and variability on Irish potato production. Further, the research interviewed two officers from meteorological department in Nyahururu and the purpose was to get more information or content on climate pattern of the Ndaragwa agro-eceological zone. The data collected using interview schedules was used to clarify and add more information that might have been left out through the filling of questionnaires.

3.3 Nature of the Data Collected

The nature of data included the demographic characteristics of the respondents, land use -specifically potato production, climate variability patterns, impacts of climate change and variability as well as adaptation practices which were obtained from different groups of people and households. Data on rainfall and temperature were obtained from the Kenya Meteorological Department and was used to analyze the trend of climate change and variability and also supported the primary data that was obtained from the respondents. Data on Irish potato was obtained from the Ministry of Agriculture in Nyandarua County; Primary data was obtained from the field through observation, use of questionnaires and interview guides while secondary data was obtained from published and unpublished sources, maps, books, development plans, journals and other relevant academic sources.

3.4 Research Instruments

The main research instruments used were, Focused Group Discussions (FGDs), questionnaires; key informant interviews (KIIs) and personal observations (Photography).

3.4.1 Questionnaires

Questionnaires were used to collect data in this study, because they could present stimulus potential to a large number of respondents at the same time, and give respondents freedom to express their views and suggestions, not forgetting that they are also anonymous thereby producing candid answers (Mugenda and Mugenda, 2003).

Questionnaires were used to collect data from the household heads and they comprised of six sections. Section 1 collected data on their background information like age of the household head, gender, and education level, source of household income and size of the land. Each of the other five sections collected information related to the impacts of climate change and variability to small scale Irish potato production and adaptation strategies. The questionnaires comprised both close-ended and open-ended questions.

3.4.2 Focused Group Discussions (FGDs)

This method was employed to determine whether the views shared through the filling of the questionnaire represented those of the larger population at the community level. It was used to collect qualitative data on people perception on the effects of climate change and adaptation strategies. The researcher through the agricultural extension officers was introduced to five different farmers group from each sub-location. The researcher together with the research team conducted the interviews in a quiet place to create a conducive environment. The discussion was based on the same issues and items on climate change and variability on Irish potato production as used in the survey and was recorded with the permission of the discussants through a digital phone and note taking.

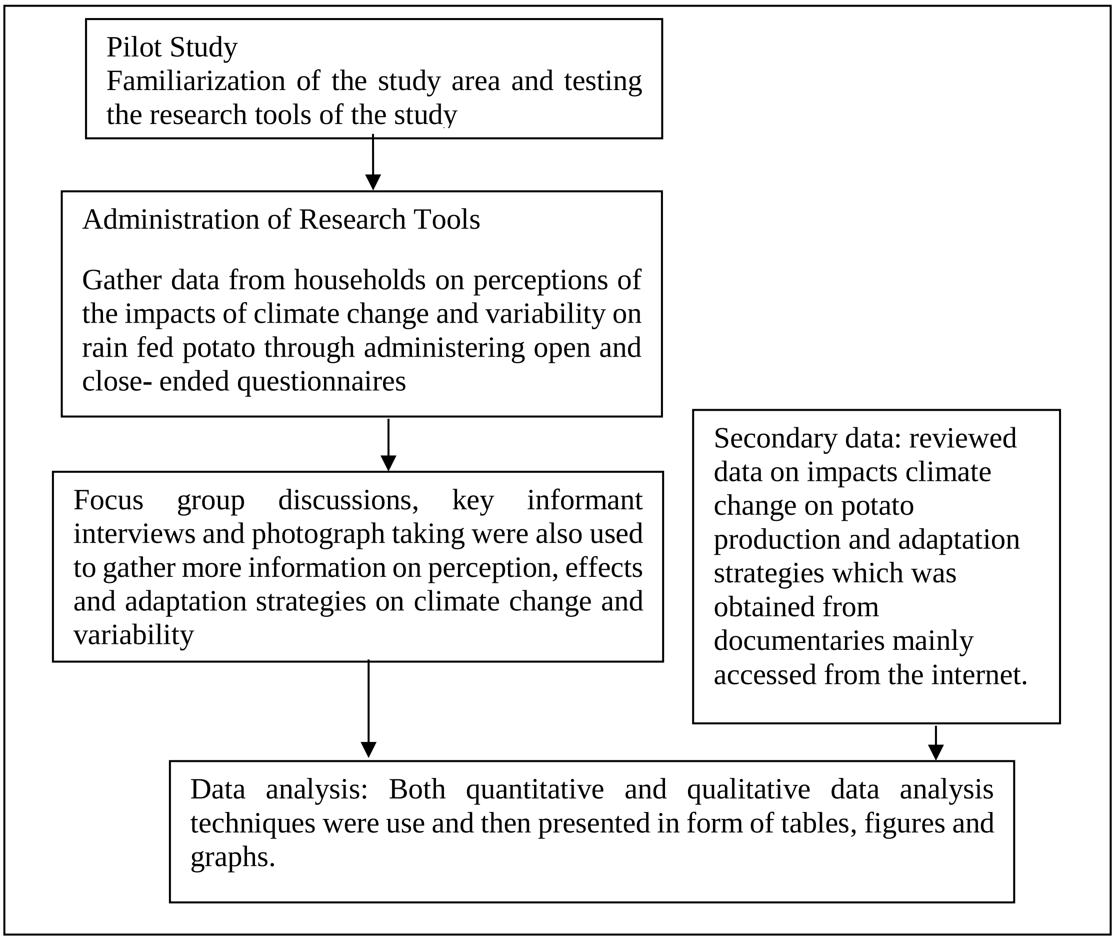
3.4.3 Key Informant Interview Schedules

A key informant interview schedule was used to gather in-depth information about effects of climate change and variability on Irish potato production and adaptation technologies used. Interviews were conducted using interview guide, which had open-ended questions and response were recorded in a note book. The use of interview guide ensured face to face interaction with the respondents which help to observe the attitude of the respondents that was not captured in the questionnaires. These instruments were used successfully in different studies including Mbaisi, (2014), Mwaniki, (2016) and Monica (2018).

3.4.4 Secondary Data Review

Secondary data were obtained from documentary sources like books, journals, theses, project annual reports, statistical abstracts that were accessed mainly through internet search using Google scholars and included data on climate change and variability on Irish potato production.

Table 3.2: Research design framework



Source: Author, 2018

3.5 Data Collection Procedure

A research permit was obtained from the National Council of Science Technology and Innovation (NACOSTI) after approval by Moi University which directed the researcher to the County commissioner office in Nyandarua County. The researcher obtained a written consent from county education officer (C.E.O) allowing us to carry out our survey in the region. The researcher recruited five research assistants because of the large number of the respondents basing on their ability to apply instructions, record responses accurately and communicate with people fluently in kikuyu language which is the major language used by the community in the study area. The research assistants were also trained on how to administer the questionnaires and on courteous ways of approaching respondents by explaining the purpose of the study before administering the questionnaires. This was to assure respondents that whatever information they provided, was to be treated as strictly confidential. After completion, the fully filled questionnaires were to be collected and submitted to the researcher on the same day. This was to limit cases of misplacing some of the questionnaires by the research assistants. The survey was well conducted and the participants were left free of their will to participate in the study.

3.6 Reliability and Validity of the Instruments

Validity is the degree to which an instrument measures what it purposes to measure, in its accuracy, truthfulness and meaningfulness of inferences that are based on the data obtained from the use of the tool, Mugenda & Mugenda (2003), while reliability refers to the consistency of scores obtained by the same persons when they are reexamined with the same test on different occasions, or with different sets of equivalent items, or under other variable examining conditions. A stable instrument is the one that gives consistent results when used on the same person several times, Kothari, (2004). To ensure that the questionnaires and the interview guide were valid and reliable, the researcher structured them to suite the objective of the study, then consulted with the expert's knowledge and lastly pre-tested and field tested the instrument before revising them to produce the final questionnaires and interview guides. According to Cohen *et al*, (2007) internal consistency of a questionnaire can be found in the Alpha coefficient of reliability which gives a coefficient of inter-item correlations of each item with the sum of all the other items. The reliability obtained was 0.882 which was adequate for the study since a coefficient Alpha of above 0.7 is deemed reliable to test the reliability of the questionnaire. A pilot study was also carried out in one sub-location within the four wards (Uruku) and this was to pre-test the questionnaire to ensure that the questions were reliable and would yield the relevant information related to effect of climate change on Irish potato production. The five trained research assistants were taken to the field for pilot study as recommended by Mugenda and Mugenda (2003) that, pre-testing the research tools is important because vague items are revealed and new suggestions incorporated to improve and adjust ambiguous questions. However, this area was not included in the final survey though it was useful for out of it, the instruments were revised as directed by the supervisors before producing the final copy of the questionnaires.

3.7 Limitations of the Study

Given that the study involved farmers in Ndaragwa Agro-ecological Zone, data collection was limited to some unique challenges including that:

1. The study was limited to association instead of causal links and therefore attenuated by the use of 35 years climate data

2. There were some missing records on climate data for some years as the researcher anticipated to analyze the data from 1980 to 2018 but was only availed with data from 1985 to 2018 on precipitation and from 1988 on temperature. This necessitated presentation data for only 33 years on precipitation and 30 years for temperature

3 The researcher also found it difficult in conducting the interviews using the official languages of Kiswahili and English, due to low level of education since these areas were remote and the poorest in the county and it turned out to be prudent to use the vernacular language Kikuyu.

4 It was initially difficult to access most parts of the study area since the rains were late and started in the month of May when the researcher was collecting the data and most roads were impassable. The rains were also starting very early in the morning which became the main challenge to the research assistants and lastly, most farmers were also too busy planting and could only have little time to respond to the questions. Despite all challenges the researcher together with the research assistants managed to administer all the questionnaires and postulates that, understanding rainfall and temperature variability and its effects will contribute to positive redress to Irish potato farmers and will result to development of future interventions for sustainable development.

3.8 Data Analysis and Presentation

The data was analyzed using both quantitative and qualitative data analysis techniques. In Quantitative techniques simple descriptive statistics such as frequencies, percentages and means were used while data on climatic parameters and potato production were further subjected to inferential statistics using correlation analysis to identify the relationships between study variables.

To determine the nature of variability of climate element**,** the study used data from the Kenya Meteorological station headquarters where the researcher requested data for a period of 38 years from 1980 to 2018 but the only available data for the region was from 1985 for precipitation and 1988 for monthly maximum and minimum temperatures. The inconsistencies in data availability at the headquarters were associated to either failure to record readings for a certain period of time or due to failure to submit the readings from the local meteorological stations to the headquarters; this therefore reduced the time frame to 33 years and 30 years respectively**.** The study sought to establish the nature of variability and change in temperature and rainfall and in order to detect changes the use of excel spread sheet was used to compute the mean, standard deviation and coefficient of variance and then presented in form of tables and graphs.

Data on objective two on the relationship between climate elements and potato productions was analyzed using excel spread sheet to calculate the annual Irish potato production and then used simple correlation analysis (pearson correlation analysis) to determine the relationship between the two variables. Correlation describes the size and direction of linear relationship between variables and is represented as:-

$$Rxy = \frac{Sxy}{SxSy}$$

Where **Sxy is the sample covariance and**

Sx and Sy are the sample standard deviations.

According to (Taylor, 1990) it is important to determine whether relationship exist between variables and if so, how significant or how strong this association is. The closer the r coefficient approaches $\underline{+}1$ regardless of direction, the stronger the existing association, indicating a more linear relationship.

Further, descriptive statistics were used in analyzing the data obtained from questionnaires. This included means, frequency and percentage using Statistical Package for Social Sciences (IBM-SPSS) Computer software version 23 where during the pre-processing stage the coding was done to simplify the data. After the analyses, results were then presented using tables, graphs and charts.

To analyze the structured sections of the questionnaires, content analysis techniques were used while data obtained from the FGDs and KII were presented in a narrative analysis. The researcher read through the responses in this section as given by the farmers and classified them into categories according to the study objectives. Each of the responses given fell under one of the categories. Frequencies of the responses were then filled and the results were tabulated. (Tubey, 2009, & Kerlinger,1978) recommended of counting the number of objects in each category after assigning each to its proper category. This enabled the researcher to quantify the data for this section.

Table 3.3: Summary on Objectives and Methodology

Objectives	Measurable Value	Research Design and Sources	Data Analysis
Nature of climate change and variability	Rainfall Temperatures	Quantitative Data from the meteorological department	Microsoft excel using totals and averages and percentages
Relationship between irish potatoes and climate elements	Potato production Climate elements	Quantitative data from the ministry of agriculture in Nyandarua County	Microsoft excels Correlation to establish whether there exists a relationship between climate elements and potato production
People perception on effects of climate change on potato production	Perceived effects	Qualitative –primary data from the questionnaires. FGDs and KII data	Descriptive statistics with the help of Statistical Package for Social Sciences (IBM-SPSS) Computer software version 23. Narrative analysis was also used
Practices and technologies related to climate change adaptation mechanisms	Adaptation strategies applied by farmers on effects of climate change	Qualitative data- primary data from the questionnaires, FGDs and KII	Frequencies, percentages, content and narrative analysis on responses on coping mechanisms applied by the respondents

3.9 Summary

This chapter gives an overview of the research method used in this study. It explains in details and also gives justification of the research design, target population, sampling procedure and sample size, nature of the data collected, research instruments used, data collection procedures and data presentation and analysis. The chapter also discusses on the validity and reliability of the research tools.

CHAPTER FOUR

DATA PRESENTATION AND DISCUSSION

4.0 Introduction

This chapter deals with the results obtained using the methods described in the previous chapter. Data analysis and presentation of the findings responds to the objectives of the study which include the nature of climate change and variability in climatic element, the connection between climate elements and Irish potato production and the results based on the responses to the items in questionnaires related to people perception on climate change and variability, impacts of climate change and variability on Irish potato production and adaptation strategies employed by farmers to achieve resilience**.**

4.1 Response Rate

The response rate refers to the percentage of the respondents who participate in the survey from the determined sample size for the research (Hamilton, 2009) and is of significant concern in a scientific study because it ensures that the percentage of the questionnaires collected are valid for data analysis. Using five research assistants, personal visits were made to administer questionnaires within eight sampled sub-locations and out of the 398 questionnaires that were administered 382 (96.0%) were completed and were found to be useful for further analysis while 16 (4%) questionnaires were excluded from the analysis for the respondents declined to participate in the survey. According to Groves *et al* (2008), if questionnaires have several missing values the risk of distorting result like mean value will be high than when they are eliminated. However, the Hamilton, (2009) said that it is more important to have a high percentage rates if the goal of the research is to establish generalization in a large population. The response rate in the current study was 96% which was above the recommended 80% by Mmaduakonan, (1998) & Okaka, (2016).

The collected data was then run in SPSS software version 23 for descriptive statistics, and only 03 (0.7%) had one missing value and they were deemed useable because the missing values were filled using average imputation to normalize the data as recommended by Rai (2019) to use the mean or median of the non-missing observations to impute values for missing data in cases where the number of missing observations is low.

4.1.1 Social economic characteristics of the respondents

The purpose of inquiring about the social- economic characteristics of the respondents was to give the researcher a glimpse of whether different categories of people are affected differently by climate change. The study therefore sought to establish on gender, age bracket, marital status, level of education, years lived in the region, years in practicing Irish potato farming and the farm size. The findings on each of the above are summarized and presented in Table 4.1 below.

From the sampled respondents, the findings reveal that 222 (58.1%) were males compared to 160 (41.9%) females. It can be observed that majority of the households are headed by male which is in tandem with most findings of studies carried out in rural areas in Kenya including Mbaisi, (2014) who found that out of 276 respondents that were interviewed, 178 were males while 98 were female.

Regarding the age category of the respondents, it was observed that 133 (34.8%) were aged between 41-50 years, 124 (32.5%) were above 51 years, 110 (28.8%) were between 31-40 while 15 (3.9%) were between 20-30 years. It is thus evident that the majority (96.1%) of the respondents were aged between 30 and above. This age range was considered to have experienced climate change which is always observed over a period of 30-35 years and therefore the information given by the respondents was deemed adequate and reliable for the study. Determining the age of the respondents was also important to understanding their views in terms of embracing new adaptation technologies as it was established by Binam, *et al,* (2005), that younger farmers are more receptive to innovation and therefore are more efficient as compared to older farmers who are less willing to adapt to new practices and inputs.

Based on marital status, the findings show that 311 (81.4%) of the respondents were married, 61 (16.0%) were single while 10 (2.6%) were separated. This was important in providing information about the farm management from different stand-points. With the majority being male and married, impacted on Irish potatoes production because there is sharing of responsibility and they have enough time to manage their land as compared to single or separated whose production might be affected by other non climatic factors. According to Nyagaka, (2009), male headed households have better access to information and services and therefore farm management by men attain higher production than those managed by women.

Furthermore, the level of education was also investigated basing on the level of formal schooling and from the findings it was observed that 234 (61.3%) of the respondents had only attained primary education, 111 (29.1%) had gone through secondary education, 21 (5.5%) had no formal education, 14 (3.7%) were certificate holders from the college while only 2 (0.5%) had a 1st degree. This finding concurs with previous studies on small scale farmers in rural areas in Kenya that show that majority of household heads have only attained primary education and this was associated with their acquisition and use of technical advice, making of decisions including efficient use of input (Kaguongo., *et a l* 2008; Orina, 2009). However, the information the respondents provided was actually what they have experienced and not what they read through therefore grasping the real perception from the respondents.

In regard to the years lived in Ndaragwa, majority of the respondents 175 (48.8%) indicated between 31-40 years, 138 (36.1%) between 20-30 years, 58 (15.2%) between 41-60 years while 11 (2.9%) over 61 years. It is thus evident that majority had resided in the area for at least more than 20 years and they are believed to have enough experiences on climatic trends and their effects of Irish potato which enhanced the value of the information provided.

The researcher also sought to establish the years the respondents have been practicing Irish potato farming in Ndaragwa. The findings show that majority 220 (57.6%) have grown Irish potatoes for over 10 years, 87 (22.8%) between 2-5 years, 48 (12.6%) between 5-10 years while 27 (7.1%) less than 2 years. This also means that the majority had acquired enough skills and knowledge on Irish potato growing and they stood a better position to explain on the causes of potato increase or decrease. Orina, (2009) observed that the more years spent on Irish potato farming predisposes farmers to better farming techniques through learning by doing. Experience is an important positive determinant of a farmer's level to detect any changes that affect the production.

Lastly, regarding the size of the land, the findings show that (62.8%) of the respondents had less than 1 acre, 119 (31.2%) had 2-5 acres, 15 (3.9%) had 5-10 acres while 8 (2.1%) had over 10 acres respectively. The majorities were small scale farmers and had less than an acre land because the current study was focusing on small scale farmers.

Table 4.1: Socio-economic characteristics of the Respondent

Item	Categorization	Frequency	Percentage
Gender	Male	222	58.1
	Female	160	41.9
	Total	**382**	**100**
Age bracket	20-30	15	3.9
	31-40	110	28.8
	41-50	133	34.8
	Above 51	124	32.5
	Total	**382**	**100**
Marital status	married	311	81.4
	Single	61	16
	Separated	10	2.6
	Total	**382**	**100**
Level of education	None	21	5.5
	Primary	234	61.3
	Secondary	111	29.1
	College	14	3.7
	University	02	0.5
	Total	**382**	**100**
Yrs lived in Ndaragwa	20-30	138	36.1
	31-40	175	48.8
	41-50	58	15.2
	Over 50	11	2.9
	Total	**382**	**100**
Yrs farming Irish	Less than 2 yrs	27	7.1
	2-5	87	22.8
	5-10	48	12.6
	Over 10 yrs	220	57.6
	Total	382	100
Size of land	Less than 1acre	240	62.8
	2-5 acres	119	31.2
	6-10 acres	15	3.9
	Over 10 yrs	8	2.1
	Total	**382**	**100**

Source (survey data, 2019)

Besides growing Irish potatoes, the respondents also participated in other activities as shown in Figure 4.1, with the majority 30.4% involved in mixed farming, 29.3% livestock keeping, 22.8% maize growing, 11.5% maize and beans, 2.7% have businesses, 1.8% beans farming, 1.1% bees keeping while 0.8% deals with tree planting.

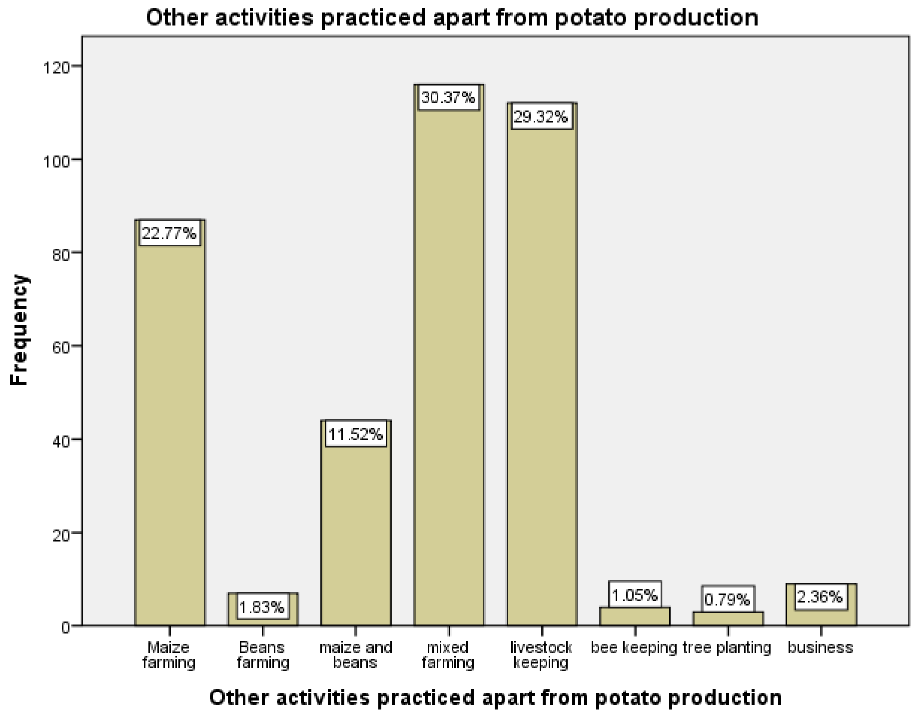


Figure 4.1: Other activities carried out apart from Irish potato farming

4.2 Nature of Variability and Change in climate

The study sought to establish the nature of variability and change in climate elements in this case Temperature and rainfall in Ndaragwa Agro-ecological Zone in Nyandarua County. The data analysis in tables and time series was guided by the availability of the data from meteorological station head quarters between the year 1985 and 2018 for rainfall and between 1988 and 2018 for temperatures.

4.2.1 Nature of variability and change in rainfall

In order to detect change in the climatic parameters, data on rainfall over a period of 33 years was analyzed. The data was divided into two sub-sets (between 1985-2001 and 2002-2018) and computed. The subset was equally divided and monthly mean, standard deviation; maximum and minimum rainfall in the region was computed. From Table 4.2, it is clear that there has been a shift in the rainfall characteristics over the region. For example, comparing the means between the two subsets, the dataset reveals that there has been an increase in the rainfall especially during the second half of the year which includes the short rain season apart from the month of June and July which experience low rainfall in the second subset. The rainfall during the first half of the year seems to have reduced apart from the month of March and May while the month of April the rainfall remained constant. These results collaborated with the information shared during the Key Informant category iii, (meteorological officer 1) interviews where it was reported that in recent year's short rain season; rainfall has been increasing and becoming more reliable and predictable than during the long rain seasons. This was also in line with the previous study by Karanja, (2013) who found that rainfall was unfavorable in Oljoro-orok during the long rain season while the short rain season contributes a lot to the increasing trend on the annual rainfall.

Table 4.2, (data-set one) also clearly depicts that the region has been receiving heavy rainfall throughout the years with months between April and August receiving extreme high rainfall events that often lead to flooding. These seasons coincide with the first growing season of Irish potato that causes potato rotting and withering of vegetative part prematurely. The findings corroborate with the information obtained through FGD1 (male participant) where it was reported that some years back their problem was heavy rainfall throughout the year that could lead to flooding especially on the lower

Zone of Shamata and Kanyagia damaging a lot of potatoes through rotting of tubers while still on farms. However, data-set two clearly portray changes in rainfall trends of the region. Information on Figure 4.3; reflect a bi-modal rainfall distribution with peaks in April, May and August in long rains separated by two months of June and July that receive moderate rainfall. The information obtained from the agricultural extension officer was that the two months of June and July have positive impacts on Irish potato first season growing period because potato production requires moderate rainfall during their flowering and harvesting time. However, the officer reported that in recent year's rainfall is unpredictable and they are experiencing late onset of rain which affect the planting period and the general production of Irish potato.

Table 4.2: The Temporal variation in the rainfall Data

Dataset		JAN	FEB	MAR	APRI	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC
Sub-set one	Mean1	39.6	29.4	63.58	114.34	105.77	120.92	130.45	141.49	61.20	59.05	62.86	47.21
	STD1	65.9	41.56	58.52	82.11	55.00	48.73	40.34	51.91	60.39	45.84	39.95	36.81
	Max1	245.20	155.20	174.80	278.00	231.80	223.40	198.20	245.00	236.10	174.10	159.20	136.80
	Min1	0.00	0.00	0.00	9.60	40.30	44.70	42.90	78.60	0.40	4.00	14.70	2.60
Sub-set two	Mean2	29.20	27.19	71.24	115.34	111.89	97.05	80.11	154.11	79.72	70.41	74.91	75.19
	STD2	32.01	41.85	63.43	77.54	45.43	51.19	30.80	59.55	72.51	44.28	44.36	72.70
	Max2	91.40	176.70	204.00	288.90	206.30	232.20	190.30	241.40	299.10	118.90	166.50	245.00
	Min2	0.00	0.00	0.00	22.10	29.40	28.60	27.00	35.80	0.00	7.80	19.00	4.40
Whole set	Mean	34.42	28.30	67.40	114.84	108.83	109.99	105.28	147.80	70.46	63.73	68.89	61.20

In Kenya, annual rainfall follows a strong bi-modal seasonal pattern (ROK, 2012). Generally, precipitation comes in two seasons in a year which has given rise to the popular terminologies of the ‘long rains’ that occurs in the month of march and may and the ‘short rains’ that occurs in the month of October to December. However, some previous writers (Ogendo, 1988; and Kimani 2016) point out that some regions in Kenya have three peaks making these regions to be categorized under tri-modal seasonal pattern. In another article on geography of Kenya, Kareri, (2015); points out that Nyahururu for example has a more complex pattern and show three peaks hence tri-modal pattern. In contrary, Figure 4.3 reflects Nyahururu to have a bi-modal seasonal pattern with peaks in April and August, this corresponds with MoALF (2016) and Nyandarua County Government (2013) report which point out that Nyahururu rainfall is bi-modal with long rains starting from March to May and short rains from September to December with ranges in annual precipitation being quite high between 1200mm to 750mm and seasonal precipitation varying substantially from year to year. This is thus a manifestation of changes and variability in climate as years goes by.

Further, Figure 4.2 shows a comparison of the monthly mean rainfall over the whole period and over the two sub-periods. Mean 1, (data set between 1985 and 2001) reflect that the region uses to receive rainfall throughout the year with heavy rains in long rain seasons starting in March and extending to August and short rains beginning in September and gradually extending to February. This shows that rainfall has been reliable and predictable and farmers could even predict their coming. The result concurs with the information shared during the FGD 2 (female participant) where it was reported that planting rain commonly known as (Bura ya Mahanda) was starting on 15th March and by then every farmer had already planted their seed only waiting for the rains that could not disappoint them. However, in mean 2, (between 2002-2018) the rainfall pattern shows a variation tendency with some months like January, February, June and July showing a decreasing trend while March, May and August show an increasing trend. The August peak coincides with the harvesting time of Irish potatoes which come with several hiccups, like poor road networks, increased cases of potato rotting and also hinders proper harvesting which likely reduce production and increase the cost of production. These findings were in line with information received from the Key Informant category i (farmer no2), where he lamented that production of Irish potato has become so costly because rainfall starts very late delaying planting seasons and eventually affecting harvesting time to August which coincides with heavy rains commonly called (Mbura ya Ngano) hindering harvesting and increasing cost of transportation to the market place and from the farm.

The reducing trend in month of June and July also reflect a clear picture that the region has experienced climate change. This is likely to affect production because as seen in Table 4.2, onset of rainfall is delaying affecting planting date and therefore the flowering and bulking seasons that requires adequate water supply coincide with the month of June and July. Lastly figure 4.2 reflects a clear change in short rain seasons where rainfall has been increasing as compares to the past years. These findings collaborated the previous studies, which predicted that rainfall in East Africa regions will be increasing particularly the short rains season (OND), which is greatly influenced by El Nino like walker circulation response to global warming (Monica, 2018; Tierney *et al*, 2015). According to GOK (2013) National Climate Change Action Plan 2013-2017, indicates that rainfall trend shows mixed signals with some locations indicating slightly decreasing trend due to a general declining in the long rain seasons while the short rains seasons showing positive trends in some location which is associated with short seasons extending into January and February in recent years.

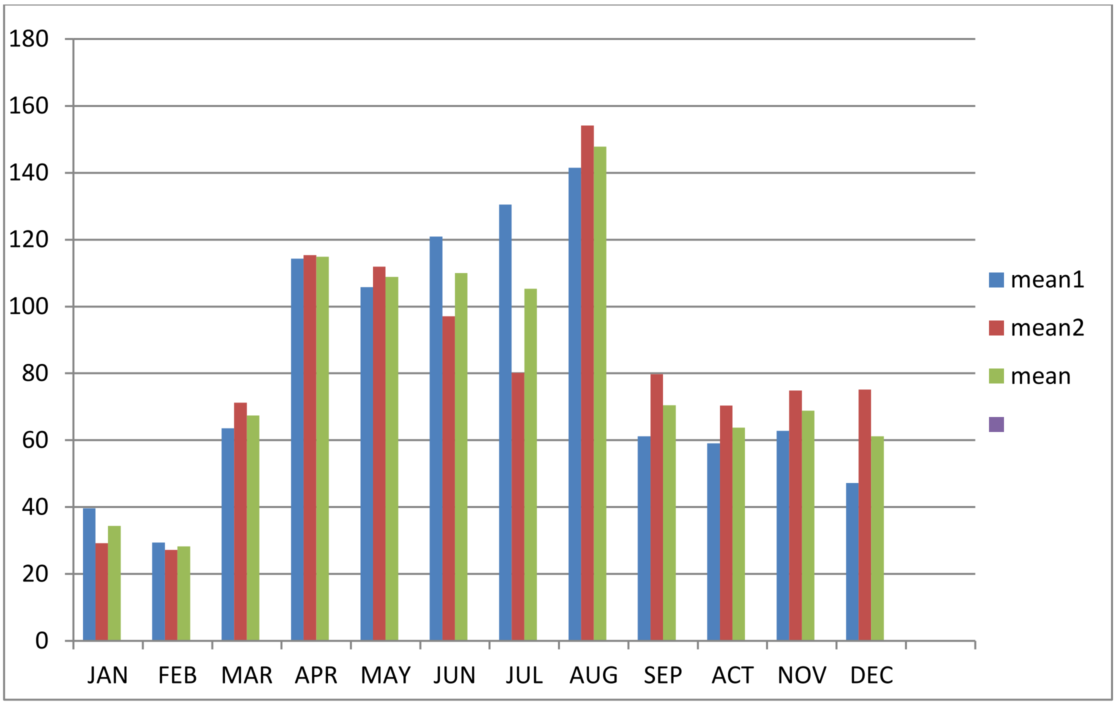


Figure 4.2: Comparison between the Monthly Mean Rainfalls over the Whole Period and over the two Sub-periods

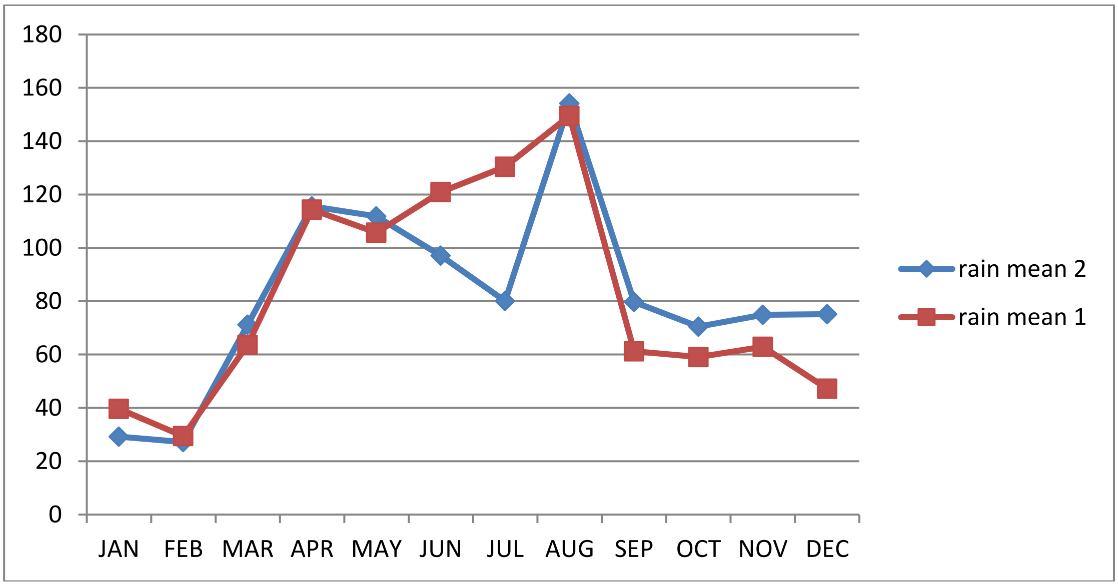


Figure 4.3: Monthly Mean Average for data set one and data set-two

Notably, the annual average rainfall amount over the years has slightly increased as shown in Figure 4.4. The annual mean rainfall trend line in the region from 1985 to 2018 depicts a slight tendency for increasing rainfall in the region. However, the rainfall has been varying from year to year with the dominant peaks observed in the year 1988, 1997, 1998 and 2013 which may be linked to Ebdon Effects (Quasi Biennial Oscillation), the El Nino and La Nina associated with sun spot cycles respectively. This finding corroborated with Karienye, *et al* (2012) who found that there was a sharp increase in the amount of rainfall received between 1997 and 1998 which were highly influenced by the El Nino.

According to a report by World Bank, (2012) the El Nino is normally followed by a prolonged dry period known as La Nina and from the analysis, Figure 4.4 also reflects that the region received rainfall that is below average with the year 2000, 2009 and 2017 recording extreme low rainfall. This average low rainfall is associated with droughts that have led Ndaragwa to be categorized semi-arid region which has a significant effect on Irish potatoes production.

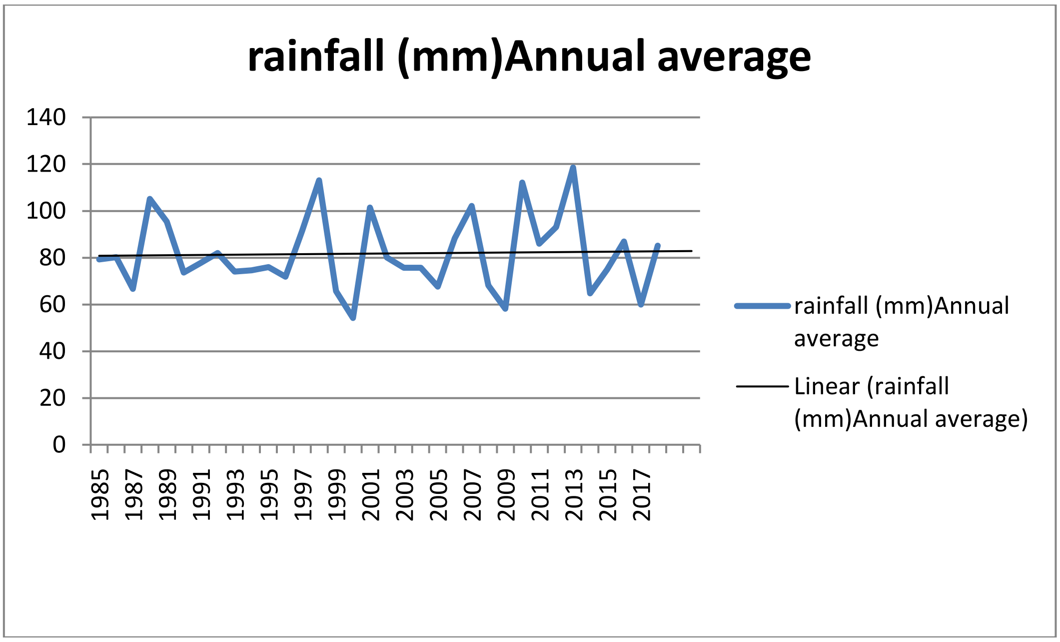


Figure 4.4: Annual Average Rainfall Data Trend for the years 1985 -2018.

Result in Figure 4.5 and 4.6 show the annual rainfall data trends for the long rains seasons and short rains seasons. From Figure (4.5), it is clear that there has been a slight change in rainfall during long rains for the trend line indicates a slight positive increase while in Figure 4.6 change is well manifested with trend line showing positive trend meaning that there has been an increase in rainfall between 1985 and 2018 during short rain seasons. It also shows variability of rainfall in different years with the highest rainfall peaks noticed in the year 1998, 2007, 2001, 2010 and 2013 while the lowest rainfall peaks noticed in 1996, 2000 and 2017 respectively. The differences in rainfall variation between long rains and short rains seasons in Ndaragwa can be associated with slightly increasing rains reported during the annual rains in the recent years.

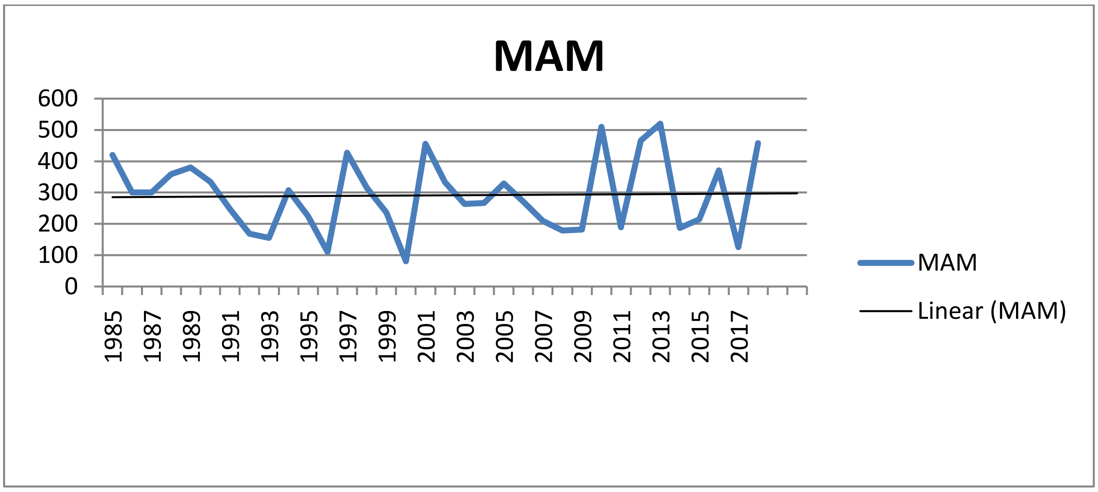


Figure 4.5: Time series of the month of March, April and May Rainfall

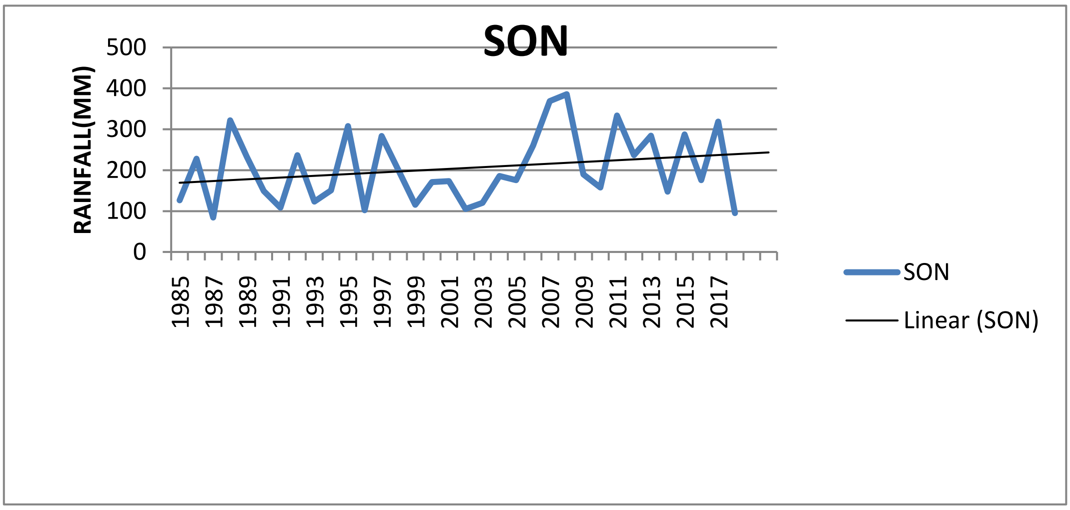


Figure 4.6: Time series of the month of September, October and November Mean Rainfall

For better understanding on rainfall variability of the region, variability index was used to compute dataset which clearly shows that rainfall has been varying. From Table 4.3 the annual rainfall variability ranges from +362.6 in the year 1998 to -344.5 in the year 2000. Rainfall variability is also significant during long rains seasons as well as short rains seasons with the ranges varying between -214.4 in 2000 to +214.4 in 2010 in long rains and +191.1 in 2008 to -99.5 in 2018 during short rains period.

Table 4.3: Annual and seasonal rainfall variability index for data set

Year	*Annual rainfall Amount / variation mean=994.84*		*Long –rain seasons Amount / variation Mean=295.06*		*Short Rain seasons Amount/ variation Mean=194.6*	
1986	*962.7*	*-32.1*	*300.4*	*+5*	*228.1*	*+33.5*
1988	*1261.1*	*+266.3*	*358.4*	*+63*	*322.0*	*+127.4*
1990	*883.9*	*-110.9*	*334.1*	*+39*	*149.3*	*-45.3*
1992	*984.1*	*-10.7*	*168.6*	*-126.5*	*236.2*	*+41.6*
1994	*895.9*	*-98.9*	*307.9*	*+12*	*150.3*	*-44.3*
1996	*862.7*	*-132.1*	*110.8*	*-184.3*	*102.3*	*-92.3*
1998	*1357.4*	*+362.6*	*314.5*	*+19.4*	*200.6*	*-6.0*
2000	*650.3*	*-344.5*	*80.7*	*-214.4*	*170.5*	*-24.1*
2002	*961.5*	*-33.3*	*333.6*	*+38.5*	*105.0*	*-89.6*
2004	*908.8*	*-86.0*	*266.4*	*-28.7*	*185.9*	*-8.7*
2006	*1059.1*	*+64.3*	*271.0*	*-24.1*	*260.2*	*+65.6*
2008	*818.1*	*-176.7*	*178.4*	*-116.7*	*285.7*	*+191.1*
2010	*1346.1*	*+351.3*	*509.5*	*+214.4*	*157.5*	*-37.1*
2012	*1117.4*	*+122.6*	*466.4*	*+171.3*	*236.8*	*+42.2*
2014	*777.3*	*-217.5*	*186.8*	*-108.3*	*147.7*	*-46.9*
2016	*1043.7*	*+48.9*	*371.1*	*+79.0*	*175.2*	*-19.4*
2018	*1022.2*	*+27.4*	*457.5*	*+162.4*	*95.1*	*-99.5*

4.2.2 Nature of variability and change in maximum temperature in Ndaragwa

Nyandarua County is reasonably cool with most regions in the county receiving less that 15^{o}C annually. However, since 1981 (MoALF, 2016), climate has been observed to change. During the first wet seasons the region has experienced a moderate 1^{o}C increase in mean temperature and in the second season temperature has increase at 0.5^{0}C.

Table 4.4 provides the comparison of the monthly mean, standard deviation, maximum and minimum temperature for two sub-set data which clearly indicate that there is a general increase in the mean maximum temperature for all months. It can be observed that the month of March has been recording the highest daily temperatures with the maximum of 26.4^{0}C. Figure 4.7 shows that temperatures have been high during the first half of the year with its peak in the month of February and March while July and August record the lowest temperatures which may be associated with the increase in cloud cover. Results from Figure 4.8 depict the time series trend of the temperatures from the year 1988 to 2018. From the figure, it can be observed that temperatures have been increasing throughout the year except the month of February and March which show constant tendency.

These results collaborated with the information obtained during the FGDs and Key Informant interviews where the Key Informant Category ii (Agricultural officers 2) reported that there has been a general increase in temperatures in the region allowing some crop varieties like maize that could not grow in the past years to growing. In FDG 2 (male participant) also reported that temperatures are increasing to an extent that they are now forced to get into their farm by six in the morning since they can no longer work up to mid-day because the soils and the environment are becoming too hot to sustain. The results also reveal that there has been variations in temperature with the month of July and August being the coldest months which are commonly associated with frost bite. The same information was shared during the Focus Group Discussion 4 (male participant) where the participant reported that the occurrence of frost bite is increasing especially in the month of June, July and November affecting Irish potatoes in both first and second growing seasons. This increased occurrence of frost bite was associated with the wide range between maximum temperature and minimum temperature which is experienced in the region. According to Nyandarua county (2013) The highest temperatures are recorded in the month of December, with a mean average of 25^0 C while the lowest is recorded in the month of July, with a mean average temperatureof 12^0 C. this was attributed to the cold air rises during clear nights on the moor lands of the Aberdare Ranges that flows down the Plateau, through the valleys west of the plateau. The temperatures in these valleys can fall to between 1.2^0 C and -1.3^0 C which last for few hours before sunrise. This was in line with Monica, (2018) who found that frost bite occurs regularly affecting 100% of the respondent and damaging all kind of crops in Kieni region. The observation also agreed with other reports which reported that the world will continue to experience frost waves despite the fact that the world is warming up (Monica, 2018; Morshrik, *et al*., 2011 & FAO, 2005)

Table 4.4: The Temporal Variation in the Maximum Temperature

Sub-set		J	F	M	A	M	J	J	A	S	O	N	D
one	Mean1	22.3	23.6	23.7	22.7	21.7	20.9	19.8	19.9	21.6	21.6	20.4	20.9
	STD1	1.5	1.30	1.0	1.0	0.8	0.8	1.0	0.7	0.9	0.9	0.6	0.81
Sub-set two	Mean2	22.6	23.5	23.8	22.7	22.1	21.5	20.6	20.6	21.8	22.1	20.9	21.4
	STD2	1.04	1.09	1.44	1.1	0.7	0.9	0.8	0.9	1.00	0.8	0.86	0.9
Whole set	Mean	22.4	23.5	23.7	22.7	21.9	21.1	20.2	20.2	21.7	21.8	20.6	21.1

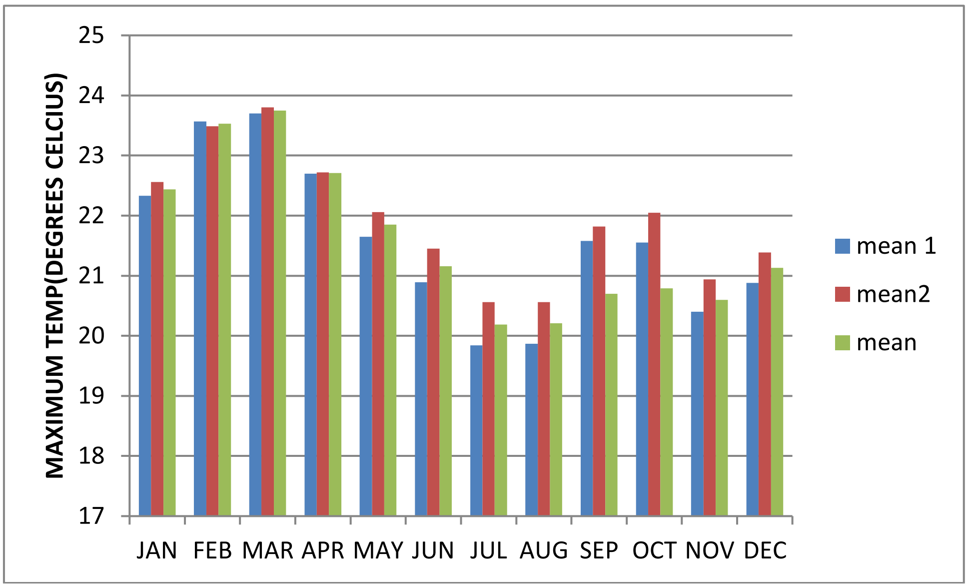


Figure 4.7: Comparison of the monthly mean maximum temperature over the whole period and over the two sub-sets

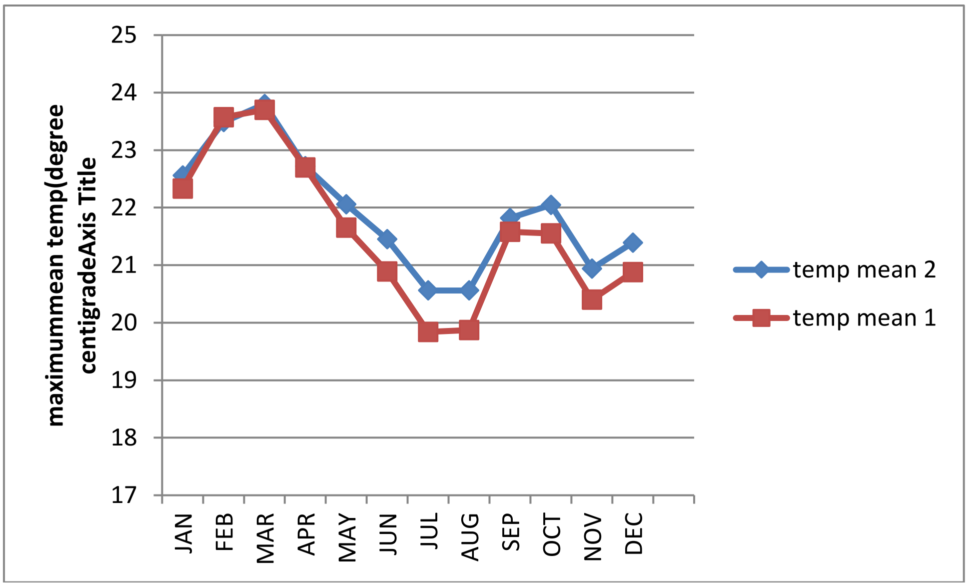


Figure 4.8: Monthly Maximum means Temperature Data set 1and 2

The result from annual mean maximum temperature Figure 4.9 indicates that 2017 was the warmest year with the annual mean of 23.1^{0}C. The trend line also shows a clear indication that the region has experienced a general warming since the 1980s

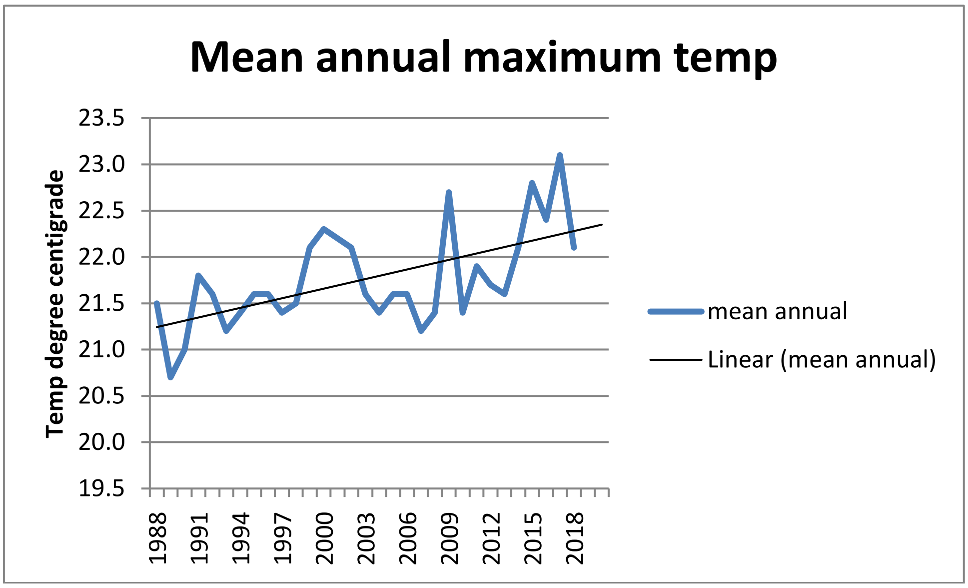


Figure 4.9 Annual Maximum mean Temperatures

4.2.3 Nature of variability and change in Minimum temperature in Ndaragwa

Comparing the monthly mean and standard deviation of the minimum temperature, Table 4.5 shows that temperature has generally increased during the study period. The highest change in minimum temperature is observed in the month of February and September with the range of 0.8^0C and 0.9^0C respectively. The month of January depicts a constant tendency in both sub-sets although the standard deviation shows some slight change. Results in Figure 4.10 also show that the month of April and November have the highest minimum temperatures while September recorded the lowest minimum temperatures. Similar observations were made by Kimani (2016) in Kenya, where he noted that in Uasin-Gishu County there is general increase in the monthly minimum temperature for all the months with highest minimum temperatures in April and the lowest in September.

Table 4.5: Showing monthly mean and standard deviation for the two data sets and the whole data

Data set-1		*J*	*F*	*M*	*A*	*M*	*J*	*J*	*A*	*S*	*O*	*N*	*D*
	Mean1	*7.2*	*6.6*	*7.6*	*8.6*	*7.9*	*7.3*	*7.4*	*7.2*	*5.9*	*7.2*	*8.7*	*8.5*
	STD1	*1.2*	*1.0*	*0.9*	*1.0*	*0.9*	*1.0*	*1.1*	*1.0*	*0.7*	*0.8*	*0.9*	*1.4*
Data set-2	***Mean2***	*7.2*	*7.4*	*8.1*	*9.0*	*8.6*	*7.7*	*8.1*	*7.6*	*6.8*	*7.8*	*9.1*	*8.7*
	STD2	*1.3*	*0.9*	*1.0*	*1.1*	*1.1*	*1.0*	*1.3*	*0.7*	*0.9*	*1.1*	*1.0*	*0.9*
TOTAL MEAN	***MEAN***	*7.2*	*6.9*	*7.3*	*8.7*	*8.1*	*7.5*	*7.7*	*7.4*	*6.3*	*7.5.*	*8.9*	*8.6*

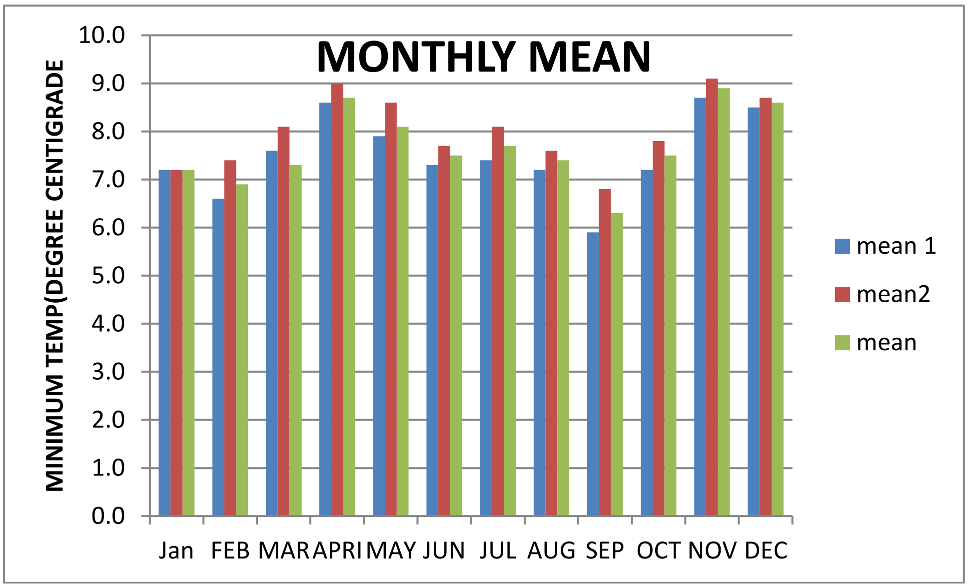


Figure 4.10: Monthly minimum mean temperatures

Temperature time series of the monthly mean minimum temperatures were also plotted to clearly portray the scenario of the trend for the year 1988-2018 variation and change. The results in Figure 4.11 clearly confirm that the minimum monthly temperature in the region has a tendency of a constant rise throughout in the recent years. The month of September has been recording the lowest minimum temperature of 6.8^{0}C while the month of April and November recorded the highest minimum temperatures of 9.0^{0}C and 9.1^{0}C respectively. The increment of the minimum temperature is more pronounced than that of the maximum temperature. This is in line with (Mbaisi, 2014) that did a study on impacts of climate change on agricultural production and found out that the minimum temperature has been increasing at a a rate of 0.02^0 C. According to (GoK, 2010 b) reports, central Kenya which is one of the most productive areas in the country has been experiencing significant change in temperature and precipitation trend, the region's minimum temperature has been increasing since 1960 with magnitude of 0.8-2.0^0 C while the trend of maximum temperature has been increasing with a magnitude of 0.1-0.7^0 C.

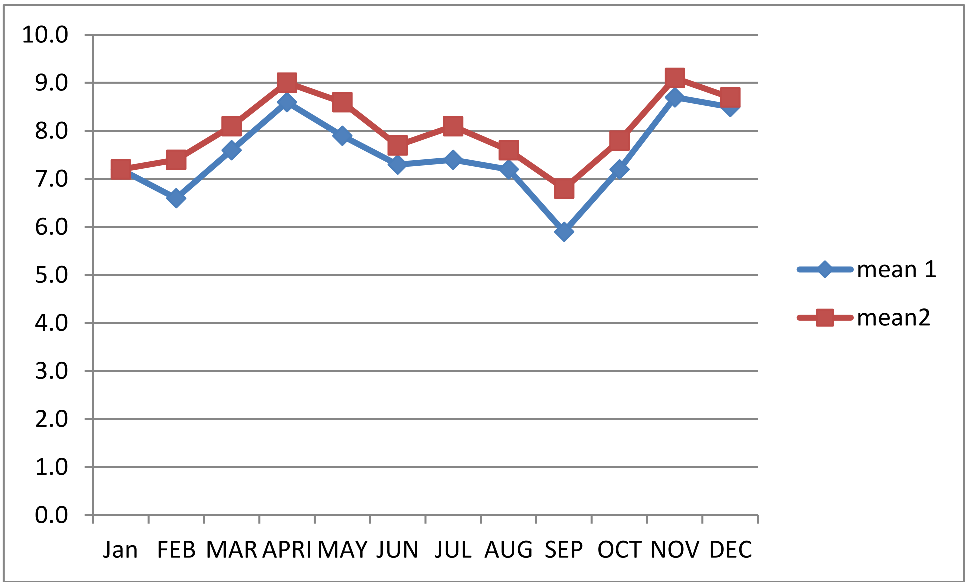


Figure 4.11: Trend lines between mean 1 and mean 2

Data in Figure 4.12 reveals that there is a wide range between maximum and minimum temperature in the region implying that the temperatures recorded at night are still very low compared to those recorded during the day. According to participants in one of the FGDs it was reported that frost bite occurs due to wide range between maximum and minimum temperatures. They reported that before the fall of frost at night, they experience a very clear sky and very high temperatures during the day but at night the temperatures drop so low to freezing point. However, as observed in Figure 4.10 minimum temperatures are also increasing and according to Kinh'uyu, *et al*, (2000) who analyzed the trends of maximum and minimum temperatures in Eastern Africa reported that Eastern African generally exhibit night time warming that will increase frost free zones favorable for agriculture. In contrast, Hijman, (2003), said that despite the Earth warming up, future potato yields could decrease in many regions because potato tuber initiation and development are much more sensitive to high temperatures.

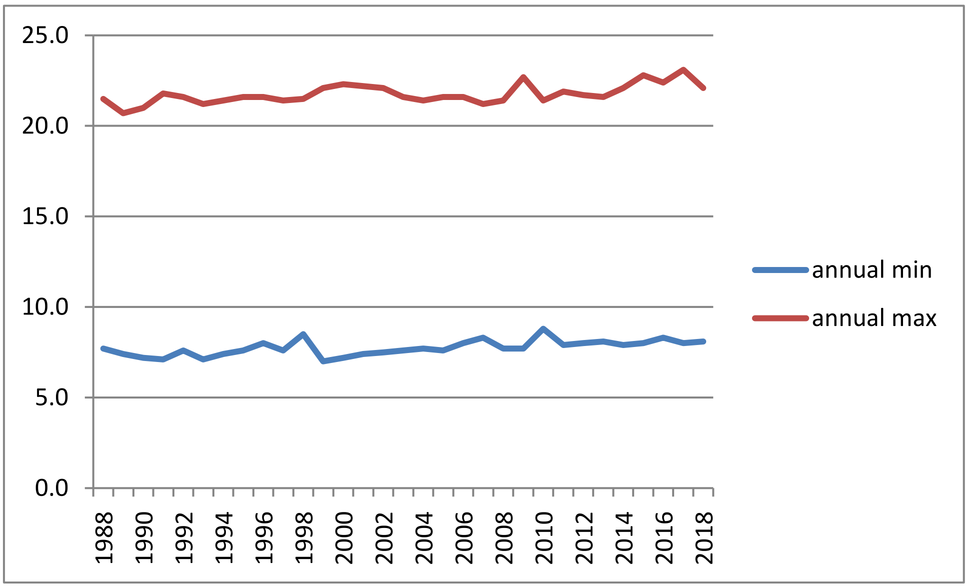


Figure 4.12 Annual mean maximum and minimum temperatures

4.3 Farmers Perception on Climate Change and Variability

The knowledge and understanding of climate change and variability by the respondent was very essential in this study in order to weigh farmers understanding of the phenomenon. For effective climate change adaptation strategies Chinwe, (2010) said that local knowledge should be tapped and combined with other knowledge systems. To communicate effectively about climate change, it is critical to know how people understand it (BBC world service Trust, 2010; Okaka, 2016). The respondents thus were asked whether they are aware that climate change and climate variability is taking place, how they receive information about it, whether they have noticed change or variability in climate and to rate their experiences using the likert scale. Their responses are presented in form of Table 4.6.

Table 4.6: Awareness that Climate Change is Taking Place

Awareness that climate change is taking place	**n**	**%**
Yes	365	95.5
No	6	1.6
Don’t know	11	2.9
Total	**382**	**100**

The results in Table 4.6 reveal that out of 382 respondents, 95.5% are aware that climate change is happening; 1.6% indicated that climate has not changed while 2.9% stated that they don’t know. The findings therefore show that the majority of the respondents are aware that climate change is taking place and it collaborated the information shared during the interview with the meteorological officer 1, who reported that climate in the area is changing and that drought incidences are increasing approximately after every 4 to 5 years which was not the case in the past years. The findings also compared favorably with those of Okaka, (2016), who found that 96.6% of the respondents were aware that climate change was taking place. However, although the current study focused on perception of farmers awareness on climate change which is similar to a number of previous studies, the study comparatively registered higher percentage, for example, Nkwusi, *et al* (2015) in a study done in Lagos State of Nigeria registered 79.04%, Fosu-Mensah, *et al* (2010) in Ghana registered 80% and Kidanu *et al* (2016) in Ethiopia registered 81.9%. In Kenya, Mutembei *et al (*2017) did a study on farmer’s perception, exposure and responses to climate change and variability in Mwea and found that 75.3% of the respondent perceived change in climate. Elsewhere, Mbaisi, (2014) on the impacts of climate change on agricultural production in Kenya indicated that 75.7% of the farmers reported to have experience decrease in precipitation while temperatures have been increasing. This implies that though the percentages might vary from one location to the other, majority of the respondents have perceived changes in climate and are able to describe the phenomena in their own experience.

Further, in an attempt to capture whether the respondents are aware that climate variability is taking place, they were asked to respond using yes, no and Don't know. From the findings Table 4.7 revealed that majority 75.7% of the respondents indicated that they are not aware; 19.4% are aware that climate variability is taking place, while 5.0% stated that they cannot exactly tell whether there is climate variability. Although the percentage of the respondents implies that the majority are not aware whether climate variability is taking place, it was captured that generally, lay people would explain climate change in terms of delayed or erratic rainfall or unexpected drastic change in temperature which they could not complehend whether it was climate variability, the information shared in FGDs and Key Informant interview revealed that the occurrence of climate element have been varying between years with some seasons receiving early onset, heavy rainfall and high temperature while in other years they receive reduced rainfall which can begin as late as May or June with frequent drought and flash floods and therefore becoming more unpredictable and unreliable.

Table 4.7: Awareness that Climate variability is Taking Place

Awareness that climate variability is taking place	**n**	**%**
Yes	74	19.4
No	289	75.7
Don't know	19	5.0
Total	**382**	**100**

Capturing some of the expressions obtained from farmer's association group (FGDs) it was revealed that climate change and variability is taking place in Ndaragwa. The main indicators pointed out were increased temperatures, reduced rainfall and increased cases of frost bite, flood and drought. The chairperson for example said:

> "*Weather pattern has changed, the rainfall was beginning in February to May, then one month of June would be abit dry then we receive heavy rains in July and August followed by light rains from September. Today (pause and shake the head) we are receiving rainfall as late as May or June which is even unpredictable, June and July are becoming dry and cold with cases of frost bite increasing that damage our potatoes and august we receive very heavy rainfall accompanied by hailstone and foggy causing heavy floods especially on the lower side. Aaah! Things are bad we are suffering and if the government can help us to drill boreholes it can save us. Please tell them things are bad!" (***FDG, 1 chairperson)**

It was even more interesting getting the information from elderly farmers who were able to explain the phenomenon of climate change in a more elaborate manner giving more reliable examples due to their experience and knowledge of previous climatic conditions in the region. For example, one of an elderly farmer had this to say (in Kiswahili verbalism but translated)

> *"Aaaah msichana wangu! hali ya hewa imekuwa mbaya, (pause) nikikumbuka miaka ya 1965, huku kulikuwa baridi sana na hatukuwa tunapanda mahindi na maharagwe juu haikuwa inakuwa. Mvua nayo ilikuwa ikinyesha karibu kila mwezi lakini tulikuwa na mvua tatu, yakwanza tuliita 'Maguna Ngombe' hii ilikuwa ya kupungusa njaa ya December na Januari na hivo ilikuwa inasaidia ngombe na ilikuwa inanyesha February. Mvua ya pili tuliita 'Bura ya mahanda' hapa ndio tulikuwa tunapanda na kila mtu tarehe 15 mwezi wa tatu alikuwa*

> *amemaliza kupanda viazi na minji, nayo ilikuwa inanyesha kuanzia katitakati ya mwezi wa tatu hadi mwezi wa tano. Mvua ya tatu tuliita 'Bura ya Ngano' hii ilikuwa mvua kubwa na sababu ya kuiita hivo ni juu ya kuharibu Ngano kwa hivo ilibidi wakulima wa ngano wavune kabla ya hii mvua kunyesha mwezi wa saba na wa nane. Huku viatu ilikuwa ni gumboot watoto kwa wazima na jacket mzitu. Lakini saa hii mambo imebadirika mvua imepungua na joto ikawa nyingi, siku hizi hata slippers tunavaa (akicheka na kuuliza swali) siunaona mambo imebadiriaka? (aaah my daughter! Weather situations are bad (pause) if I can remember back in 1965, this region was too cold and we were not growing maize and beans. Rainfall was throughout the year though we had three distinct rain seasons. The first one we were calling it "Maguna Ngombe" and this was to reduce hunger and dry season experienced in December and January and therefore it could save the cows from dying and it use to rain in February. The second rain was called "Bura ya mahada" this was now the planting season and every farmer had to plant potatoes and peas by 15th march and it use to rain from mid-march to May. The third rain was called "Bura ya ngano" this was heavy rain and was given the name because of spoiling wheat and therefore every wheat farmer was supposed to have harvested before it starts in the month of July to August. Here in this region, we use to wear gumboots only, both kids and adults and heavy jackets. But today things have change with the rain reducing and temperature increasing. Today we are even wearing slippers (while laughing and pose a question) don't you see thing are changing? (**KII, farmer no.2)***

In Table 4.8, the respondents were requested to rate how they have perceived the intensity of climate change and variability in Ndaragwa using a 3-point likert scale ranging from low, medium and high to show the extend how climate change and variability risks or problems have affected the region. The respondents were also to mention the most experienced risk related to climate change and variability as presented in Figure 4.13.

According to the results, Table 4.8 reflected that drought cases have been common. The majority of the respondents (79.6%) indicated that intensity of drought occurrences has been high, 21.7% medium while only 3.7% said it has been low. On whether the respondents experienced frosts, 61.0% indicated that the cases have been high, 31.7% medium while 7.3% low. In case of humidity occurrences, the result reveals that 86.1% experienced low cases, 13.6% medium while only 0.3% indicated high. Cases of pest and diseases was reported to be high (58.4%), 41.1% saying it was medium while 0.5% indicated they were low. On whether high temperature cases are experienced, 60.2% indicated that the cases were high, 29.3% medium while 10.5% said the cases were low. As to whether rains have been unpredictable, 78.5% indicated that those cases have been high, 16.8% indicating medium while 4.7% saying it has been low. On Cases of heat waves, 37.4% indicated low, 34.0% medium while 28.5% believed they were high. Finally, on cases of floods, 53.7% said the cases were high, 20.7% medium while 25.5% said they were low.

Table 4.8: Shows the Intensity of Climate change and variability Risks on Irish Potato in Ndaragwa

	Low	Medium	High	Total
Drought	14(3.7%)	83(21.7%)	285(74.6%)	382(100%)
Frost	28(7.3%)	121(31.7%)	233(61.0%)	382(100%)
Humidity	329(86.1%)	52(13.6%)	1(0.3%)	382(100%)
Pest& diseases	2(0.5%)	157(41.1%)	223(58.4%)	382(100%)
High temperatures	40(10.5%)	112(29.3%)	230(60.2%)	382(100%)
Unpredictable rains	18(4.7%)	64(16.8%)	300(78.5%)	382(100%)
Heat waves	143(37.4%)	130(34.0%)	109(28.5%)	382(100%)
Floods	98(25.7%)	79(20.7%)	205(53.7%	382(100%)

A number of climatic related risks/problems were evidence in Ndaragwa. However, the most remarkable risk of climate change and variability experienced in the region was frost, drought and water scarcity as shown in figure 4.13

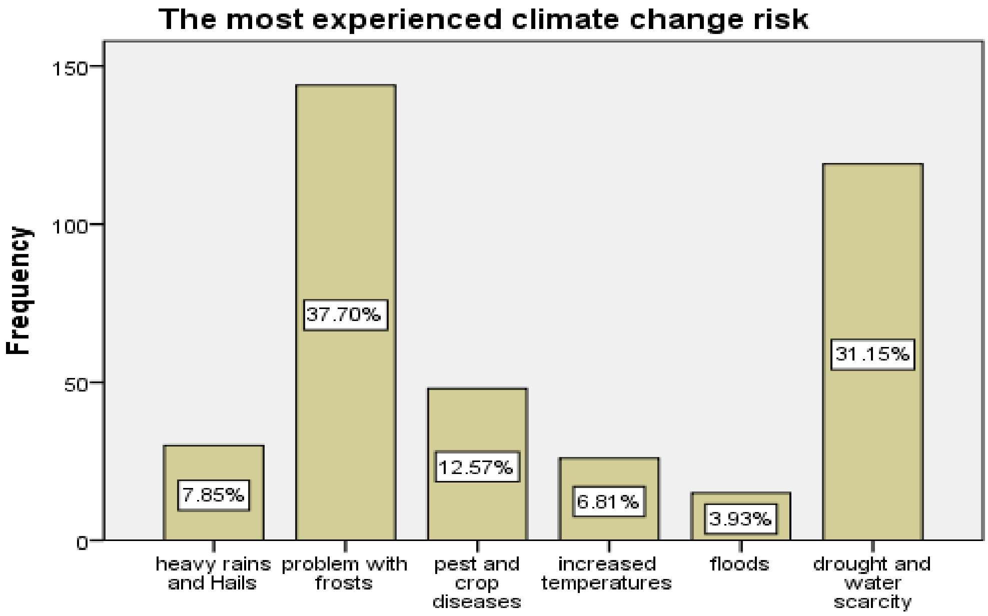


Figure 4.13: Climate Related Risk Affecting Irish Potato Production

4.3.1 Respondents Perception on Change in Rainfall

Generally, respondents from Ndaragwa agro-ecological zone indicated that they had observed changes in rainfall pattern with 86.4% (330) farmers indicating decrease in rainfall in the region whereas 9.4% (36) of them indicated increase in rainfall and only 4.2% (16) farmers indicated that they have not observed any change in the amount of rainfall received. Using a likert scale of 1) strongly disagree 2) disagree 3) neutral 4) agree and 5) strongly agree, Table 4.9 clearly rate farmers' responses on perception on how rainfall has been changing and from the responses, it is clear that rainfall pattern has been changing with 49.9% strongly disagreeing that rainfall has been increasing, 58.8% disagreeing, none agreeing while 0.3% strongly agreeing. On receiving extremely high rainfall the majority 57.3% disagree with it, 30.1% strongly disagree, 2.4% are uncertain, 9.9% agree while 0.3% strongly agree.

The result also indicates that only 0.8% of the respondent are strongly disagreeing that rainfall has decreased, none of the respondents disagreed, 6.8% are neutral, 40.8%

agreeing that rainfall has decreased and 51.6% are strongly agreeing that the rainfall in the region has decreased. On whether they receive extremely low rainfall only one respondent 0.3% strongly disagrees, 7.9% disagree, 7.3% are neutral, 47.6% agree and 36.9% strongly agree.

The question on late onset and early onset of rain, 38% of the respondents strongly disagree that rains start early, 59.4% disagree, 2.1% were not sure, only 0.5% agree and none of the respondents strongly agree. From Table 4.9, 61.3% strongly disagree that there is no change in rainfall, 34.6% disagree, 4.2% were neutral and none agree or strongly agree that there is no change in rainfall and lastly majority 56.8% agree that during the main rain season, rainfall has decrease.

Table 4.9: Rates Farmers' perception on climate change (Rainfall)

Rainfall pattern	Strongly disagree	Disagree	Neutral	Agree	Strongly agree	Total
Increase in rainfall	179 (49.9%)	198 (58.8%)	4 (1.0%)	None	1 (0.3%)	382 (100%)
Extremely high rain	115 (30.1%)	219 (57.3%)	9 (2.4%)	38 (9.9%)	1 (0.3%)	382 (100%)
Decrease in rainfall	3 (0.8%)	None	26 (6.8%)	156 (40.8%)	197 (51.6%)	382 (100%)
Extremely low rain	1 (0.3%)	30 (7.9%)	28 (7.3%)	182 (47.6%)	141 (36.9%)	382 (100%)
Early onset of rainfall	145 (38.0%)	227 (59.4%)	8 (2.1%)	2 (0.5%)	None	382 (100%)
Late onset of rainfall	8 (2.9%)	12 (3.1%)	13 (3.4%)	157 (41.1%)	192 (50.3%)	382 (100%)
No change in rainfall	234 (61.3%)	132 (34.6%)	16 (4.2%)	None	None	382 (100%)
Main rain season rain reduce	None	1 (0.3%)	1 (0.3%)	217 (56.8%)	163 (42.7%)	382 (100%)

Discussion with one of the agricultural officers confirmed that:

> *"Actually this place is one of the dry regions in Nyandarua county meaning that generally it receives low rainfall, however, the situation is worsening because we are experiencing a reduction in rainfall amount below the area's mean average that ranges between 800mm-900mm, however I cannot claim that this happens in all the months of*

> *the years because in some months the rains are very high to a point where we experience floods (pauses) in my own observation, rainfall differ after every 4-5 years when we even experience extremely low rainfall that leads to drought.*** ” (KII, agricultural officer 2)***

Apart from describing how they perceive climate change and variability; the respondents were also asked how they received information on climate change. From the findings it can be observed that the respondents receive information from the different sources. Table 4.10 shows that the majority 59.7% accessed information through media, 24.1% from farmers association where, 7.3% used traditional methods like observing the sky and certain animals' behaviors to understand climate change, 3.1% accessed information through agricultural extension officers while 2.9% learn from the internet and 1.3% attend some training where they receive information. This is in line with (Mwaniki, 2016) in his study on Kenyan farmer's perception and adaptations to climate change who reported that 68% of the farmers indicated that they receive weather updates through the media and the information is very reliable.

Table 4.10 Sources of accessing information

Sources of information	Frequency	Percentages
Media	228	59.7
Internet	11	2.9
Agricultural Officer	12	3.1
Training	5	1.3
Farmers association	92	24.1
Traditional methods	28	7.3
None of the above	6	1.6
Total	**382**	**100**

4.3.2 Farmers perception on change in temperature

During the study farmers were asked if they perceived any changes in temperature in the region and if yes to specify the changes. From the analysis the frequency shows that 100% of the respondents confirmed that temperature has increased and some of the important information that was coming up during the focus group discussion who explains that:

> *Huku baridi ilikuwa mingi karibu kila mwezi, lakini leo tunaona mabadiriko ya hali ya anga maana kuna joto (pause) kusema ukweli usiku tulikuwa tunajifunika mablanketi mzitu zile za laymondi na kuvaa sweta kubwa kubwa na watoto nao kulikuwa na zile afroni za stocking lakini siku hizi maisha imebadilika na watu hutumia blanketi nyepesi ama nandanganya (akiuliza wenzake na wote wakakubaliana naye).This region used to be very cold almost throughout the year, but today weather has changed and it is warming up (pause) infact at night we use to cover ourselves with very heavy raymond blankets and put on heavy sweater and for the kids there were those aprons that had stocking but nowadays lifestyle is changing and people are now buying light blankets or am I lying? (Asking other group members and they all supported her). (**FDG 2. Female participant)***

Another participant explained that:

> *Mimi naona kama joto imeongezeka kwasababu siku hizi vipindi vya kiangazi vimeongezeka na jambo lingine hizi mitalo za maji hazikuwa zinakauka lakini juu ya jua kali inayoongeza joto jingi hizi mitalo hata saa hii unaona venye zimekauka? According to me temperature has increased because nowadays dry seasons are increasing and another thing this water trenches used not to dry but due to high sunlight increasing temperature have you seen the trenches have dried? (**Male participant FDG 3)***

The study also used the five likert scales strongly agree, agree, neutral, disagree and strongly disagree to capture majority of farmers feeling on temperature changes. Results in Table 4.11 indicates that 48.4% farmers strongly agree that temperatures have increased, 47.9% also in agreement with the statement, 3.7% disagree that temperature has increased while none of them either strongly agree or neutral. Majority of the farmers (58.6%) disagree that temperature has decreased, 34.3% strongly disagreeing, 1.0% were neutral, 6.0% agree and none strongly agree. Most farmers who responded felt that temperature has changed and with this 50.3% strongly disagree, 31.7% disagree, 13.9% were neutral, 3.1% agreed while 1.0 strongly agree. Theresults on whether temperatures decrease in rainy seasons shows that 57.1% were in agreement with the statement, 34.6% even strongly agree, 6.3% disagree, 2.1% remaining neutral while none strongly disagree. During dry seasons, 45.8% of the farmers strongly agree that temperatures do increase, 45.3% also agree, 6.3% disagree while 2.6% were neutral and none strongly disagree. 53.4% of the farmers strongly agree that number of hot days have increased, 44.0% agree, 1.6% neutral, 1.0% disagree but none strongly disagree. Lastly, 40.6% of the farmers strongly disagree that number of cold days have increased with the majority 52.9% also disagreeing, while a fewer number 3.7% being neutral, 1.6% agreeing and 1.3% strongly agreeing.

Table 4.11: Farmer's Perception Rates on Temperature Changes

	Strongly disagree	*Disagree*	*Neutral*	*Agree*	*Strongly agree*
Temp. has increased	*None*	*3.7%*	*None*	*47.9%*	*48.4%*
Temp. has decrease	*34.3%*	*58.6%*	*1.0%*	*6.0%*	*None*
No change	*50.3%*	*31.7%*	*13.9%*	*3.1%*	*1.0%*
Temp dec in rain season	*None*	*6.3%*	*2.1%*	*57.1%*	*34.6%*
Temp inc in dry season	*None*	*6.3%*	*2.6%*	*45.3%*	*45.8%*
No. of hot days increase	*None*	*1.0%*	*1.6%*	*44.0%*	*53.4%*
No. cold days increases	*40.5%*	*52.9%*	*3.7%*	*1.6%*	*1.3%*

4.4 The Relationship between Irish Potato Production and Climate Elements

Generally, like other crops in agricultural sectors, potato also stands to be affected by change in climate, although not all elements will result to negative effects. Blom-zandstra *et al* (2015) says that a potato crop will benefit more from climate change than wheat or rice, especially from increased CO_2 levels due to increased yields and reduced crop water use if only planting can be done at appropriate times of the year. However according to information shared by a Key Informant category ii (agricultural officer 4), extreme temperature and precipitation which result to cases of drought and floods in the region have major effects on Irish potato growth and development reducing the overall production.The officers also said that yields increased with increasing rainfall but started decreasing only when rainfall was at extremes This was in line with Karanja *et al* (2017) who analyzed drought characteristics and pointed out that Ndaragwa has been experiencing extreme events in terms of rainfall that either leads to drought or flood. The author found that moderate drought was experienced in 1999 and 2000; severe drought in 2014 and extreme drought in 1987 and 2009 while in 2004, 2008 and 2013 were moderately wet years, 2012 severely wet and 1998 extremely wet years. This collaborated the information from the FGD 2 (male participant) who reported that they experienced extreme rainfall events in 1997, 1998 and 2018 where they reported a lot of rotting cases especially on the low lands although the production was high compared with 2000, 2009 and 2017 which were the driest years.

In Table 4.12, the respondents observed an overall reduction of Irish potato in their locality. The majority 64.1% reported decrease in potato production while 35.9% reported increase in potato production. This finding was in line with the information obtained during the FDGs 2 where it was reported that Irish potato in the region is highly decreasing and farmers are even trying to diversify farming by growing maize, beans and keeping animals.

The finding supported a report by the government of Kenya, which indicated that, since Irish potatoes farming was promoted in the year 1963 by introducing new varieties from German and establishment of a potato development programme in the year 1967, which was mandated to stream line production of certified seeds and resistant varieties to farmers, production of Irish potatoes improved to an extent that Kenya managed to export potatoes to India, middle East and Europe (ROK, 2012). However, between 1999 and 2007 Irish potatoes started declining and the decline is associated to poor crop husbandry, climate change including rain failure and low policy priorities (ROK, 2011). Today, the average yield of a potato in Kenya is 7 tons per hectare, against the global average of 40 to 50 tons, which is associated to lack of certified seed and climate change Growing African's agriculture (AGRA, 2017).

Table 4.12: Observed Potato Production in Ndaragwa

Has Irish potato production increased or reduced	n	%
Increased	137	35.9
Decreased	245	64.1
Total	**382**	**100**

In an attempt to understand why Irish potatoes are increasing or reducing in the region, Figure 4.14 show that, the respondents who indicated increase in production associated it with high demand and therefore majority 35.9% indicated potato as most preferable source of food in the region increasing production. This findings is supported by GOK (2015) report, which indicated that climate change is creating further stress on food and water supply leaving most Kenyans malnourished because they live on diets based on maize which lack nutritional diversity, since most of roots and tuber crops including sweet potatoes, cassava, yams and arrow roots have been declining with the declining wetlands, that have been reclaimed and settled up and therefore increasing high demands of Irish potatoes that the region growing them cannot meet.

On the other hand, Figure 4.15; show that the majority (64.1%) of the respondents who indicated decrease in production associated it with low rainfall and drought. These findings compare favorably with those of Karanja *et al*, (2017) in a study of analyzing rainfall variability on potato production in Oljororok which reported that 45% of the respondents agree that rainfall variation is the main course of decreased Irish potato yield in the region.

The information was also captured through an interview with a Key informant (meteorological officer 2), where it was reported that the area receives rainfall below the mean average of 875mm per year with extreme cases experienced in 1999, 2000, 2009, 2014 and 2017 affecting Irish potato farms in the region. This finding compares favorably to that of Karanja *et.al* (2017) who indicated that Ndaragwa receives rainfall below the mean average where the lowest average rainfall was experienced in 1984, 1999, 2000, and 2009 with 1999 and 2000 coinciding with la-Nina phenomena that followed the El-Niño rains of 1997 and 1998. According to Blom-zandstra *et.al* (2015) Irish potato shows a high sensitivity to drought and water stress especially during tuber bulking which inhibit future bulking of those Irish potatoes and it does not only decrease potato grade but also lower yield.

From an interview with KII (agricultural extension officer 3), it was clear that there has been change in climate pattern, the officer indicated that the onset of rains used to be around February and peaks in March and April. However, by mid-1980s the onset of rains has been delaying beginning in April or May and in extreme cases in June. This was associated to reduction of the planting seasons from three seasons which were: March to June, August to October and November to February to two seasons which are now: May to September and October to January and has actually led to low yield because crop density is not optimum. To add on that, the analyzed data on rainfall in Table 4.3 reflected a clear variation in rain seasons that limit farmer’s decisions in planting dates which is very crucial for growth and development of Irish potatoes. According to Muthoni *et al* (2013) change in climate will lead to shifts in areas suitable for potato production, lead to poor quality of tubers for processing and reduce yields while demand for irrigation is also expected to increase.

Although Debashis *et al* (2018) on farmer's perception to climate change on crop production focuses on crop production in general and not on Irish potatoes, they found out that increased intensity of drought was the second most important impact of climate change affecting crop production. Discussions during focus groups (FDGs) and Key Informents (KIIs) also pointed out that drought and water scarcity greatly affect Irish potatoes production. Some of their responses were:

> *Mvua imepungua sana na nyakati za kiazi kuongezeka. Kitambo hata kama mvua ingechelewa hatukua tunakosa chakula na sana sana viazi juu tulikuwa tunapanda karibu na mitaro ya maji au karibu na mto na wengine kunyunyizia maji. Lakini siku hizi mito zinakauka handi ngombe zinakosa maji hadi kufa. (recently, rain has reduced and cases of drought has increased. In the past, even if onset of rainfalls could delay, we did not have cases of hunger especially lack of Irish potatoes because we use to grow them near the trenches and streams while others could irrigate their land. But today those streams are dry up to an extent that even cows fail to get water and some end up dying.* (FGDs **4, *participant.)***

> *With the changes in climate, we are witnessing increased incidences of drought and a lot of Irish potato farmers are suffering. The rainfall pattern is changing and after every 4 to 5 years we are experiencing cases of extreme drought. For example, in the year 2000, 2007, 2009 and 2017, this area experienced drought and there was real shortage of water and most families were hungry. For sure am afraid about the future if these trends continue or worsen. **(KII 3 Agricultural extension officers)***

These expressions compare favorably with the findings of Karanja *et al* (2017), who in their study on analysis of temporal drought characteristics in Laikipia West found that Ndaragwa has been experiencing drought with cases reported in 1987, 1999, 2000, 2009 and 2014.

The concern about drought was also expressed by farmers through interview and one expressed that

> *Though Ndaragwa is one of the dry zones in Nyandarua county, drought cases are becoming more regular and the problem is that Sometimes the rains might start early and farmers plant their crops but at the flowering/ tuberization stage rains disappear and the crops end up drying up. (**K11 1, male participant).***

These findings show that Irish potatoes are drought sensitive crops and they are highly affected by drought and lack of water. Similar observation was noted by Obidiegwo *et al* (2015) in their study on stress and adaptive responses in potato and they pointed out that a potato (solanum Tuberosum L) is sensitive to drought and its sustainable production is threatened due to frequent drought episodes. In a different study on Genetic Dissection of drought tolerance in potatoes, Anithakumari (2011) found out that drought has a drastic effect on tuber yield which depends on the aggregate of morpho-physiological processes such as photosynthesis, leaf area expansion and bulking of tubers.

Further, during the FGD2, the spread and increase of pest and diseases was also linked to high rainfall and drought. The respondent (male participant) reported that extreme rainfall causing flood lead to higher spread of potato pest and diseases in farms while in other years the rainfall decreases causing accessional periods of drought that lead to water stress and increase pest that do well in warm and hot climate. This finding was supported by the information received from KII (Agricultural officer 3) who reported that, reduction of rains and increased temperatures improve the environment for pest and diseases which is among the main challenge facing Irish potato farmers in Ndaragwa region. Giving examples, the officer reported that diseases like late blight, thrives well during cool and humid climate and that it spread out by infected tubers causing a lot of damage especially during long rain seasons.

The officers further mentioned that, other diseases like early bright spread out rapidly under heavy due, frequent rainfall and warm conditions, blackleg and soft rot diseases thrive well during excessive moisture while bacterial wilt is wildly spread out by flood or during heavy rainfall. The findings were well supported by The Organic Farmer (TOF, 2015) report which shows that Kenya has been invaded by new potato pest and diseases that threatened to cut potato production by more than 80% and that the pest (Potato Cyst Nematode) is very destructive and cannot be eradicated easily.

More so, participants in FGD 4 associated poor crop germination with late onset of rains. According to a female participant, rains use to start in February all through to June and every farmer use to plant their potatoes before the beginning of the rains, however, today the pattern is totally different, rainfall is unpredictable, it delays and incase it starts early, it too high or not sufficient to sustain germination because the tuber seed decay before they germinate. These force farmers to replant again while some cannot even afford it due to high cost of the required resources. This collaborated with Jovoviv *et al* (2016) who found that intense rainfall has damaged potato production in recent years where heavy rains during planting seasons cause significant loses through seed decay which further increases the cost of production in replanting and use of herbicides to control massive diseases caused by pathogenic bacteria that damage quality of tubers and decline yield. Jovoviv *et al* (2016) further pointed out that hits of rain drop destroy the soil structure and separate soil particles making them easily moved by water down slope and if it occurs during the bulking period, the immature tubers are exposed to sunlight turning them into green colour and later wither them reducing yield.

Elsewhere, Mbaisi, (2014) found that the erratic pattern of rainfall causes increased cost of production to some of the farmers who normally plant their crops during dry season just before the onset of the rains. The author indicates the practice of early planting is only beneficial if the rains are consistent but in the event that the rains are not consistent and timely there is usually poor germination and poor emergency that may lead to re-roughing and replanting which increases the cost of production and lowers the gross margin for farmers.

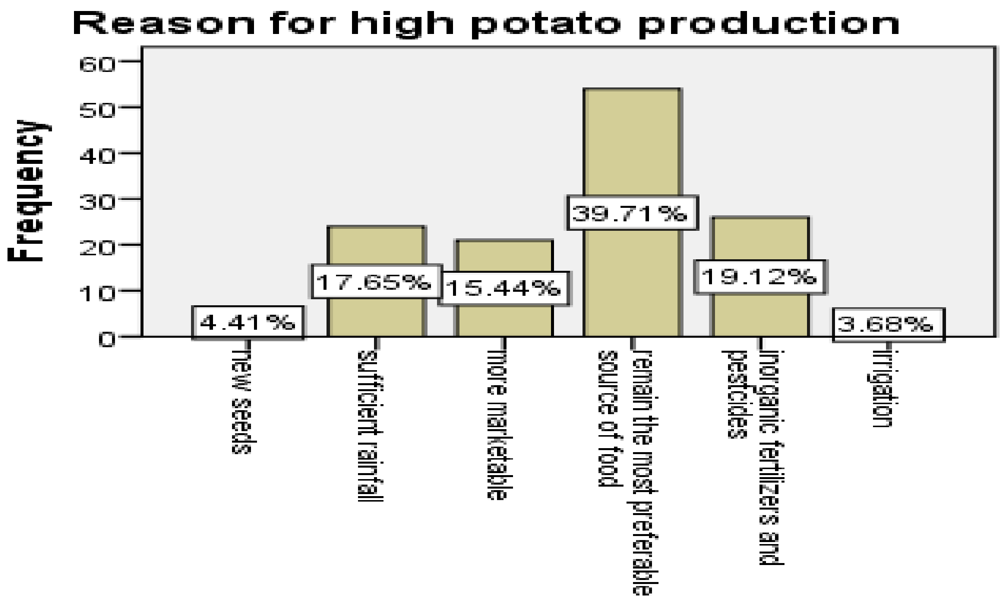


Figure 4.14: Reason for High Production

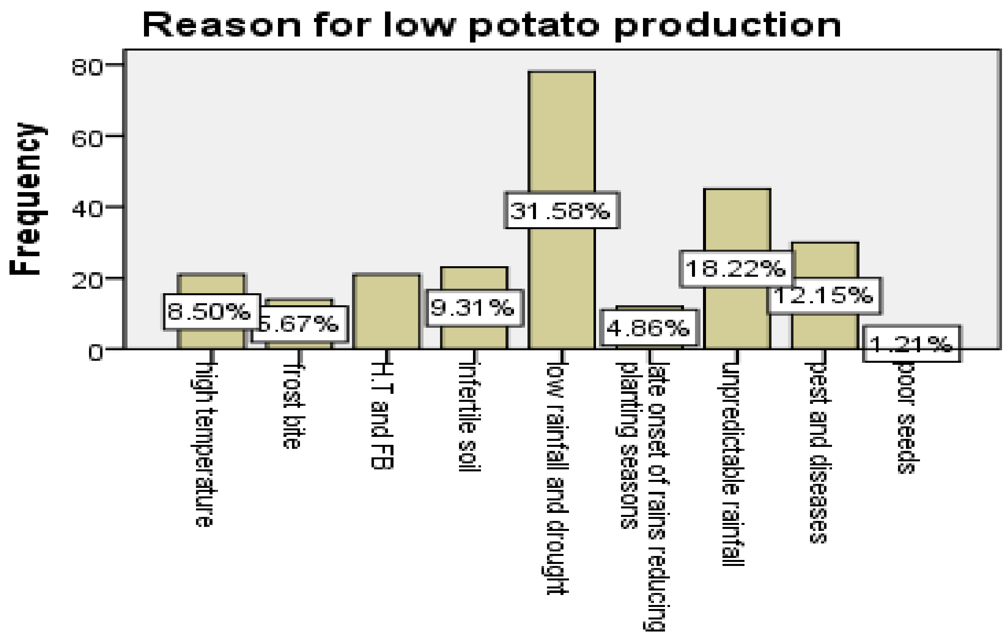


Figure 4.15: Reason for Low Production

Beside rainfall and drought, the respondents in Figure 4.15 also associated reduction of Irish potatoes with pest and diseases, infertile soils, high temperatures, frost bite and poor seeds. The information shared by the KII (Agricultural Officers 3) revealed that the area is regularly experiencing cases of adhesive frost bite that occur in January and mid-June to July. He further reported that Frost bite occur when there is no much moisture and the minimum temperatures at night are too low that freezes the moisture cell sap in the plant cell, rupturing the cell wall, killing the entire crop and turning them black. He continued that, in the past cases of frost was still reported but in the month of June and September and its effects on Irish potato was not highly felt because farmers were already in harvesting stage.

In a group discussion with FGD 4, the participants reported that frost bite cases are increasing and especially at lower Zone. According to a male participant it was reported that frost falls at around 5.00.am in the morning and can destroy the entire potato farm within hours. For instance, in 2017 most farmers in the region did not harvest in the second season because frost fell in December burning all the crops including maize, nappier grass and even trees. Another female participant added that frost bite kills even animals the moment they eat on frosted grass. The findings are supported by Kotikot *et al* (2015) who did their study on mapping frost prone area in Mt Kenya region and found that 38.4% of the area is at risk of being hit by frost especially in the months of April, May, October and November destroying most of crops in their early stages. FAO (2015) reports also show that, the world will continue to experience cases of frost waves despite the fact that the earth is warming up and temperatures are increasing. However, contrary to these findings, Njenga *et al* (2013) observed that frost occurrences were reducing with global warming.

On the basis of total yields of Irish potato in Ndaragwa, the results presented in Figure 4.16 reveal that majority of the respondents 25.39% harvest between 15-20 bags, 20.68% between 18-20 bags, 13.09% between 10-15 bags, 12.30% between 12-15 bags, 10.47% between 15-25 bags, 9.95% between 5-10 bags and 8.12% between 2-5 bags. This finding means that there has been variation in production among the respondents which is likely associated with variation in climatic elements.

According to the information received from the Key Informants (agricultural officer 1 and farmer 2) the production harvested per season is below the targeted production from the region. The extension officers reported that Ndaragwa has a potential of producing 30-50 bags of Irish potatoes per season if the climatic and non-climatic conditions are favorable. On the other hand, the KII (farmer 2) reported that production has really reduced because initially they use to harvest upto 45 bags without including the small size tubers that were considered seeds.

Such a case was also reported in a previous study by Kinyae *et al* (1996) that Irish potato yields in Nyandarua district were generally low at 1.43 metric tons per hectare because the region experienced water stress and the rains delayed causing 86% of the interviewed respondents harvest less than 12 bags per hectare while only 2% harvested yields above 37 bags per hectare. In a different study by Kenya News Agency (KNA: 2019) reported that one acre of land in Nyandarua produces 17 tons of potatoes. However, the report pointed out that if better potato management can be done, the region can produce double the amount that will even benefit farmers for higher yields and high profits.

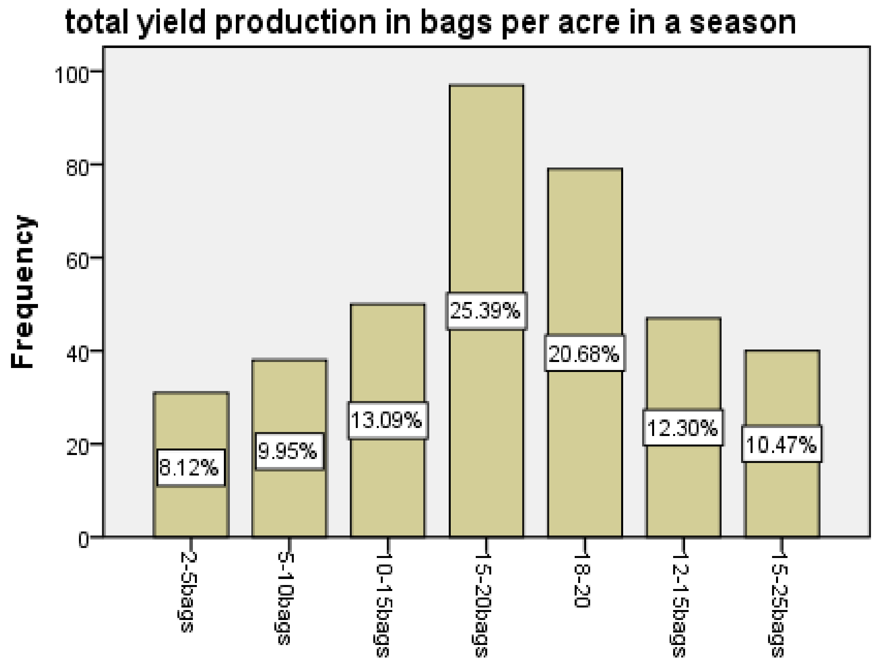


Figure 4.16: Total Yield Production

Despite the challenges experienced by the farmers in Ndaragwa, Irish potato production still remains the main source of food influencing farmer's decision in agricultural activities. This was captured from the study survey as indicated in Figure 4.17 where the majority 33.77% felt that it is still the main staple food, 20.94% indicated market availability, 17.02% indicated cultural value, 13.61% soil conditions, 10.47% indicated that it has ability to resist climatic variability, 2.82% indicated land tenure while 0.79% felt that it takes short time to grow and 0.52% indicated water availability.

The finding corresponded with the information shared during the FGDs and Key informant interviews where it was reported that Irish potato in the region is the basis of everything in terms of food and finances and therefore most people find it hard to venture into other economic activities even when production is declining. A discussion with agricultural extension officer 3 revealed that in most homesteads every dish served has to have a component of Irish potato in that even Ugali is served with a mixture of young green leaves with other traditional vegetables. The officer continues that Irish potatoes in Ndaragwa is served inform of Mukimo, boiled potatoes, Ngonja Matu (mixture of potato and maize floor starred together), roasted potato, serve with Githeri or chips especially in urban centers.

These findings are almost similar to Muthoni *et al* (2013) where they reported that Irish potatoes is always ranked 2nd from maize, a staple food that is highly fed by Kenyan population and is a major food and cash crop in Kenyan highlands widely grown by small scale farmers and plays a major role on food security in Kenya by contributing to poverty alleviation through income generation and employment creation.

However according to Info Resources (2008) report, the effects of climate change will be aggravated by change in rainfall distribution and in case there is no possibility of irrigation, yields will decrease even further down to the extent that Irish potato growing will become altogether impossible for yield decline are expected to reach up to 20-30 percent which is a threat to food security in the country.

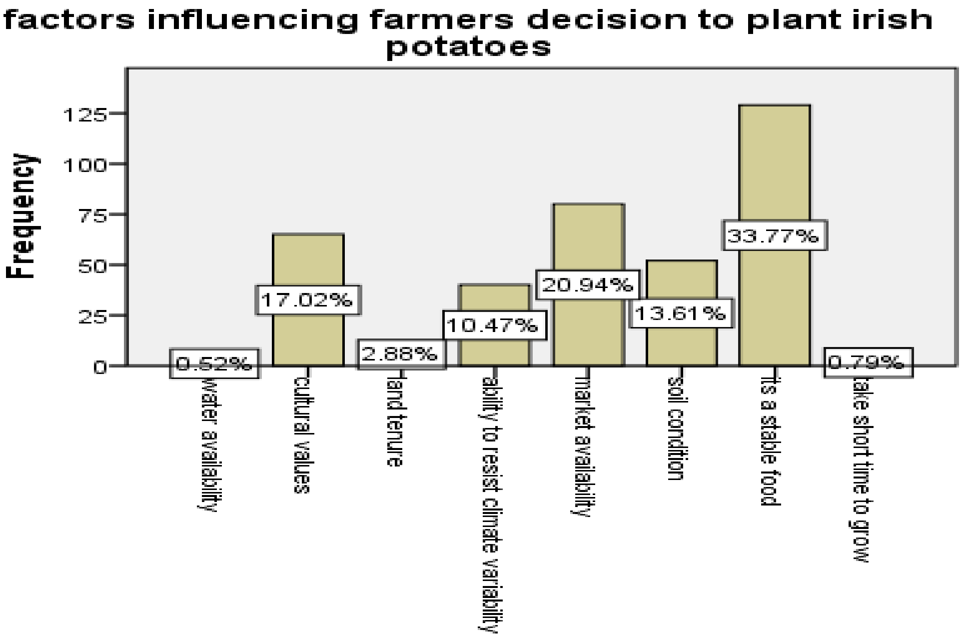


Figure 4.17: Factors Influencing Farmer's Decision

4.4.1 Hypothesis Testing on the Relationship Between Production and Climate Elements (rainfall and temperatures)

Data on Irish potato production for the last 30 years was sought from the ministry of agriculture but the only available data from the Ministry of Agriculture Nyandarua County was between the years 1999 to 2018 as shown in table 4.13. Failure of the past record was associated to poor technology where the officers reported that most production reports were not well filled and they could not manage to capture the past data in their current systems.

Table 4.13: Seasonal and Annual Potato Production from 1999-2018

	TARGETS						**Achieved**					
	Area(HA)			**production (Tons)**			**Area(HA)**			**Production (Tons)**		
Year	**LR**	**SR**	**T**	**LR**	**SR**	**Total**	**LR**	**SR**	**T**	**LR**	**SR**	**Total**
1999	1432	750	2182	6310	2400	8710	1371	420	1791	1332	502	**1834.00**
2000	2020	800	2820	3285	1548	4833	1589	500	2089	546.00	345	**900.00**
2001	2015	820	2835	8642	4546	13188	1864	720	2584	6719.71	1391.29	**8111.00**
2002	2045	940	2985	11738	6232	17970	1575	735	2310	5888.19	1701.81	**7590.00**
2003	2055	765	2820	9453	5689	15142	1975	400	2375	4324.00	2418.00	**6742.00**
2004	2000	785	2785	10845	6876	17721	1750	595	2345	5222.90	2680.10	**7903.00**
2005	1845	835	2680	8754	4214	12868	845	670	1515	3637.68	1016.32	**4654.00**
2006	2050	820	2870	7200	3124	10324	1840	520	2360	4000.00	1664.00	**5664.00**
2007	2000	700	2700	25200	7560	32760	1800	600	2400	12760.0	4334.00	**17094.0**
2008	2000	800	2800	25200	8640	33840	1550	700	2250	8974.00	5246.00	**14220.0**
2009	1820	755	2575	3184	1699	4884	1439	400	1839	653.00	450.00	**1103.00**
2010	1830	740	2570	18117	7326	25443	1475	645	2100	7581.00	5965.00	**13546.0**
2011	1875	850	2725	13950	1890	15840	1475	645	2100	645.10	2365.08	**3010.18**
2012	1925	970	2245	9914	6615	16520	925	345	1270	5507.50	3675.00	**9182.50**
2013	1355	920	2275	9014	6165	15179	923	340	1263	5007.50	3425.00	**8432.50**
2014	1318	750	2068	14310	8856	23166	730	284	1014	657.30	454.20	**1111.50**
2015	1326	820	2146	13118	8118	21236	840	345	1145	4510.00	1889.00	**6399.00**
2016	1350	800	2150	11250	6120	17370	1150	613	1763	6375.00	2257.00	**8632.00**
2017	1435	800	2235	11511	6615	18115	1370	365	1735	626.05	423.00	**1048.05**
2018	1410	750	2160	11286	6165	17451	1280	260	1540	3024.00	432.00	**3456.00**

Source: Ministry of Agriculture. Nyahururu

To examine the nature of relationship between production and rainfall, data on Table 4.14 was computed and used for analysis using Pearson's product-moment correlations and the result are presented in Table 4.16.

Table 4.14 Irish Potato Production

Years	Total yield	P.LR season	P.SR season	LR. MAM	SR. SON	Annual rain
1999	**1834.00**	1332	502	236.10	115.00	788.2
2000	**900.00**	546.00	345	80.70	170.50	650.3
2001	**8111.00**	6719.71	1391.29	455.80	172.80	1217.4
2002	**7590.00**	5888.19	1701.81	333.60	105.00	961.5
2003	**6742.00**	4324.00	2418.00	263.40	119.70	907.8
2004	**7903.00**	5222.90	2680.10	266.40	185.90	908.8
2005	**4654.00**	3637.68	1016.32	329.20	175.30	811.9
2006	**5664.00**	4000.00	1664.00	271.00	260.20	1059.1
2007	**17094.0**	12760.0	4334.00	209.50	368.60	1224.8
2008	**14220.0**	8974.00	5246.00	178.40	385.70	818.1
2009	**1103.00**	653.00	450.00	181.60	190.00	698.4
2010	**13546.0**	7581.00	5965.00	509.50	157.50	1346.1
2011	**3010.18**	645.10	2365.08	189.40	333.20	1030.9
2012	**9182.50**	5507.50	3675.00	466.40	236.80	1117.4
2013	**8432.50**	5007.50	3425.00	520.00	284.20	1422.7
2014	**1111.50**	657.30	454.20	186.80	147.70	777.3
2015	**6399.00**	4510.00	1889.00	214.70	287.10	897.8
2016	**8632.00**	6375.00	2257.00	371.10	175.20	1043.7
2017	**1048.05**	626.05	423.00	125.40	318.40	719.1
2018	**3456.00**	3024.00	432.00	457.50	95.10	1022.2

Table 4.15: Pearson moment correlation result between rainfall and production

		Annual Yield	production in long rains	production in short rains	long rains MAM	short rains SON	Annual rains
Annual Yield	P.correlation	1					
	sig-1 tailed						
	N	20					
Production in long rains	P.correlation	.976**	1				
	sig-1 tailed	.000					
	N	20	20				
Production in Short rains	P.correlation	.896**	.777**	1			
	sig-1tailed		.000	.000			
	N	20	20	20			
Short rains SON	P.correlation	.403*	.318	.514*	-306	1	
	sig-1 tailed	.039	.086	.010	.095		
	N	20	20	20	20	20	
Annual Rains	P.correlation	.400*	.418	.302	.789**	.147	1
	sig-1 tailed	.040	0.33	.098	0.000	.269	
	N	20	20	20	20	20	20

****Correlation is significant at the 0.01 level (1-tailed)**
*** Correlation is significant at the 0.05 level (1-tailed)**

The results reveal that there was a strong positive relationship which was statistically significant between production during long rains and annual total production. According to Taylor (1990), when Pearson's r is close to 1, it means that the relationship between the two variables is strong and that change in one variable are strongly correlated with change in the second variable and when it is close to 0, there is a weak relationship between the two variable and therefore change in one variable are not correlated to change in the second variable. The findings from Table 4.15 Pearson's $r=0.979$, $n=20$, $p\leq.01$ showing a strong relationship between production during long rains and annual Irish potato production. This means the two are strongly positively related and as rainfall increases during long rain season, the annual production also increases by 0.979 as well. This is also observed during the short rain seasons where $r= 0.896$ showing a strong relationship which is significant.

A positive relationship also exists between long rains, short rains and annual rainfall and Irish potato production. Long rains reveal ($r=0.201$, $n=20$, $p \leq 0.05$), which is not significant, short rains ($r=0.403$) and annual rains ($r=0.400$) which are statistically significant. This confirms that indeed the rainfall is strongly positively related to Irish potato production in all seasons and as rainfall amount increases, potato production also increases. In a similar study Karanja (2013) arrived at similar findings in which he noted that there is a strong positive relationship between rainfall amount and potato production and vice versa. The relationship between potato yield and rainfall was analyzed to test the null hypothesis H_{O1} (**There exist no significant relationship between Irish potato yields and rainfall variability in Ndaragwa A.E Zone**.) Table 4.15 shows the value of $r=0.400$ indicating a positive relationship with a sig (1-tailed) value of 0.040 which is less that 0.05 confidence level thus implying that we reject the null hypothesis because there is sufficient evidence to conclude that there is a significant linear relationship between rainfall and production since the correlation coefficient is significantly different from zero (0). This indicated that indeed changes in rainfall in either way affect Irish potato production.

In order to establish the relationship between Irish potato production and temperatures both minimum and maximum, Table 4.16 was computed and analyze using Pearson's product-moment correlations and the result are presented in Table 4.18

Table 4.16: Irish potato production and Temperatures

Years	Total yield	P.LR season	P.SR season	Annual min temp	Annual max temp
1999	**1834.00**	1332	502	7.00	22.10
2000	**900.00**	546.00	345	7.20	22.30
2001	**8111.00**	6719.71	1391.29	7.40	22.20
2002	**7590.00**	5888.19	1701.81	7.50	22.10
2003	**6742.00**	4324.00	2418.00	7.60	21.60
2004	**7903.00**	5222.90	2680.10	7.70	21.40
2005	**4654.00**	3637.68	1016.32	7.60	21.60
2006	**5664.00**	4000.00	1664.00	8.00	21.60
2007	**17094.0**	12760.0	4334.00	8.30	21.20
2008	**14220.0**	8974.00	5246.00	7.70	21.40
2009	**1103.00**	653.00	450.00	7.70	22.70
2010	**13546.0**	7581.00	5965.00	8.80	21.40
2011	**3010.18**	645.10	2365.08	7.90	21.90
2012	**9182.50**	5507.50	3675.00	8.00	21.70
2013	**8432.50**	5007.50	3425.00	8.10	21.60
2014	**1111.50**	657.30	454.20	7.90	22.10
2015	**6399.00**	4510.00	1889.00	8.00	22.80
2016	**8632.00**	6375.00	2257.00	8.30	22.40
2017	**1048.05**	626.05	423.00	8.00	23.10
2018	**3456.00**	3024.00	432.00	8.10	22.10

Table 4.17: Correlation between Production and Temperatures

		Annual Yield	Annual Min Temp	Annual Max Temp
Annual Yield	P.Correlation	1		
	sig-1-tailed			
	N	20		
Annual Min Temp	P.Correlation	.237	1	
	sig-1-tailed	.157		
	N	20	20	
Annual Max Temp	P.Correlation	-381*	-194	1
	sig-1-tailed	.049	.206	
	N	20	20	20

* Correlation is significant at the 0.05 level (1-tailed)

The correlation between Irish potato production and temperature as shown in Table 4.17 reveals that there was a positive correlation ($r=0.237$, $n=20$, $p\leq 0.05$) between annual minimum temperature and production which is not statistically significant. This confirms that with increase in minimum temperatures, Irish potato production slightly increases. However, Pearson’s correlation reveals a negative relationship (r=-381, $n=20$, $p\leq 0.05$) which is statistically significant between maximum temperatures and annual Irish potato production, implying that when annual maximum temperature increases by one-unit potato production reduces by 0.381 and on the other hand when annual minimum temperatures increase by one unit, the potato output increases by 0.237. The findings compare with that of Mbugua (2016) findings who observed that mean maximum temperatures have a negative relationship and are significant while the coefficient of mean temperature has a positive relationship and is significant. In contrast, Naintoh *et al* (2018) discovered that correlation analysis between potato yield and temperature reveals a very weak positive relationship ($r=0.02$) and is not statistically significant. From Table 4.17 the calculated r-value for minimum temperature gave 0.237 (a weak positive relationship) and sig. (1-tailed) value of 0.157 which is more than 0.05 confidence level implying that we retain the null hypothesis (H_{O2}) **that there exists no significant relationship between Irish potato yields and temperature (min temp) variability in Ndaragwa A.E Zone** because there is insufficient evidence to conclude that there is a significant linear relationship between min temperatures and production since the correlation coefficient is not significantly different from zero (0). More so, r value reveals a weak positive relationship meaning that changes in mean temperature has less impact on potato production. However, on maximum temperature r- value reveals a negative relationship (r=-381) and a sig.(1-tailed) value of 0.049 which is less than 0.05 confidence level thus implying that we reject the null hypothesis ($H_{O2)}$ **that there exists no significant relationship between Irish potato yields and temperature (max temp) variability in Ndaragwa A.E Zone.** This indicates that there is a significant relationship which is negative revealing that when maximum temperatures increase the Irish potato production is negatively affected.

Finaly, as for the results having either low or high potato production the significant predictors are rainfall and temperature ($r=0.979$, $n=20$, $p\leq.01$ in rainfall and ($r=0.237$, $n=20$, $p\leq 0.05$ in temperatures. This means that 97.9% are likely to have high production during high rainfall while only 23.7% are likely to have high production in high temperatures. These findings are almost similar to Karanja (2008) in Kenya where the researcher reported that rainfall and temperatures were the important predictors to having high productions, as changes in one variable correlates with the changes in the second variable. In alater study among residents of Tanzania Juma (2015) found that the residents were likely to expand the cultivated areas basing on the changes of temperatures and rainfall.

4.5 Perceived Impacts of Climate Change and Variability on Small Scale Irish Potato Production

In this section, farmers were asked to explain how they perceive effects of climate change and variability on Irish potato production in Ndaragwa agro-ecological Zone, and Table 4.18 presented their responses indicating several effects perceived by different farmers in different climatic elements.

Table 4.18: Perceived Effects of Climate Change on Irish Potatoes

Effects on potatoes	High Rain N (%)	Low Rain N (%)	High Temp N (%)	Low Rain N (%)	High Temp N (%)
Poor germination	15 (3.9)	42(11.0)	- -	60(15.7)	**117(30.6**)
Rotting of potato farms	215(56.3)	- -	- -	- -	215(**56.3**)
Pest and Diseases	52 (13.6)	69(18.1)	111(29.1)	- -	232(**60.8**)
Poor quality tubers	73 (19.1)	23(6.0)	30 (7.9)	- -	126 (**33.0**)
Wilting & drying of crops	6 (1.6)	21 (5.5)	58 (15.2)	10(2.7)	95 (**25.0**)
Poor production	7 (1.8)	40 (10.5)	47(12.3)	7(1.8)	101(**26.4**)
Food shortage	- -	89(23.3)	60(15.7)	9(2.4)	158(**41.4**)
Slow growth	1(0.3)	37(9.7)	- -	47(12.3)	85(**22.3**)
Good &high yields	6(1.6)	- -	- -	- -	6(**1.6**)
Crop failures	5(1.3)	9(2.4)	- -	72(18.8)	86(**22.5**)
Fast growth of potato	2(0.5)	--	24(6.3)	- -	86(**22.5**)
Frost bite	250(**65.4**)	- -		- -	72(18.8)
Total	182(100)	182(100)	182(100)	182(100)	

In general, Table 4.18 reveals that 65.4% of the respondents perceived Frost bite as the major effects of climate change on Irish potatoes in region with 46.3% specifically perceiving the effects during low temperatures, 13.6% in Low rainfall while 5.5 in High temperatures. This finding collaborated the information shared during FGDs and Key informant interviews where it was reported that frost is the most hazardous climatic related risk affecting Irish potato crop in Ndaragwa. These come up strongly during the focus group discussions (FGDs) where a farmer lamented that:

> *"I have lost my crops severally due to frost bite caused by frost that occurs during clear cold nights. The problem with frost is that there is no cure or preventive herbicide to control it as compared to diseases and when it occurs it destroys all the crops and incase of the left over's we are forced to harvest them prematurely which reduces the potato quality and production* ***(FGD 4, male participant)***

Another participant had this to say:

> *Huku shida yetu kubwa ni Baaa' inaharibu viazi sana kwa sababu huwa inamwagika wakati viazi zimetoa mauwa karibu kuweka viazi.*

> *Inaeza choma shamba lote mzima Kwa usiku mmoja tuu na shamba lako lote liwe nyeusi. Akiendelea' shinda ya baaa (frost) ni ati huwa inachoma kila kitu sio nyasi, thaara, mahindi, maharagwe, miti, mboga na hata kuuwa ngombe zikila ile nyasi. (Here in Ndaragwa our main problem is frost, it damages Irish potato at a greater extent because it falls during the flowering time when they are at bulking stage. It can burn your entire land within one night turning it black. "Continuing…" the problem with frost is that it bites everything including Napier grass, maize, grass, beans, vegetables, kales, cabbages, trees and even killing cows that may feed on the burnt grass**. (FGDs, 4th female participant.)***

The information received from a Key Informant (agricultural officer 1) concurred with the farmer's perception, where he reported that cases of crop failure is common especially on the lower side which is caused by adhesive frost that occur in January, mid-June to July and current cases being reported in November. The Officer further said that Frost bite occur when there is no much moisture and the minimum temperatures at night are too low to freeze the moisture cell sap in the plant cell, rupturing the cell wall and killing the entire crop. He continued that in the past, cases of frost were still reported in the month of June and September but its effects on Irish potato were not highly felt because farmers were already in their harvesting stage. However today, due to reduced and late onset of rains frost fall during the flowering stage freezing the foliage part of the potato and causing total crop failure.

The findings supported Monica (2013), In a study carried out in Kieni Constituency Kenya on enhancing climate change adaptation who found that 100% of the respondents reported to have suffered from frost damage reducing the quality of planting materials and causing poor establishment of crops.

Plate 4.1 clearly show a potato farm before the occurrence of frost while Plate 4.2 show the same farm after it was affected by frost in Shamata ward within one night in 2018 during the short rain season.

Plate 4.1. Irish potato farm before the occurrence of frost bite

Plate 4.2: Same Irish potato farm after the occurrence frost bite

Sources: field work, November, 2018 in Ndaragwa Central ward, Shamata.

Further, respondents perceived pests and diseases as another major effect of climate change and variability on Irish potatoes production. In Table 4.20 indicates that 60.8%

of the responded perceives pest and diseases with 29.1% perceiving the effect during high temperature, 18.1% in low rainfall, and 13.6% in high rainfall while none observed it in low temperature. The finding was supported by the information received from the FGDs where they reported to have perceived increase cases of pest and diseases. A male participant reported that nowadays it is impossible to grow Irish potatoes without the use of fungicides and pesticides because without them, there is high loss and poor-quality yield harvested. The participant continued that despite of them using costly pesticides and fungicides, the loss and damage of Irish potatoes is still high because there are new pest and diseases that they have never experienced and they are not responding to these chemicals. This was in line with The Organic Farmer (TOF, 2015) who reported that Kenya has been invaded by new potato pest that threatened to cut potato production by more than 80% and the pest (Potato Cyst Nematode) are very destructive and cannot be eradicated easily.

In another discussion with the focus group, it was reported that the occurrences of these pest and diseases depend on the amount and distribution of rainfall because like late bright disease is common during high rainfall while most pest and aphids increases during the dry seasons. These findings compared favourable to those of Munyuli *et al* (2017) in their study on farmers perceptions, believes, knowledge and management of potato pest in Congo, who found that late blight during rainy seasons would cause up to 56-100% of potato yields loss while late onset of rains or prolonged drought induced high pest attack that reduced potato yields. In an earlier study on estimation of yield loss in Kenya, Olanya *et al* (2002) found that farmers had observed high infections of pest and diseases in the early rainy season when climatic conditions are favorable for disease development. Munyuli *et al* (2017) also pointed out that, climate change and variability is likely to accelerate pest infestations in the field because most pest outbreak is observed after disturbances in the rainfall pattern occur. The following expressions from FGDs captured the attention of the researcher even more as participant in different groups lamented that:

> *"shinda ingine hapa ni magonjwa na wandudu wakati wa mvua na pia mvua ikipungua. (akipeana mfano) ugonjwa kama muthingitho' (bacterial wilt) showing an example of a sick plant as shown in plate 3.) na zingine zenye hatujui majina huenea sana wakati wa mvua na kuambukiza sehemu kubwa la shamba usipong'oa mimea iliyonaugonjwa. Dariri ya hii ugonjwa ni "kuhoha (wilting) kwa kiasi kama hii (akionyesha kiasi) na hutoa viasi zenye madoa ya black kwenye macho. Pia, wadudu kama fuko huongezeka wakati wa mvua na kuleta madhala mengi kwa wakulima. Nayo mvua ikipungua viazi zinakuliwa na wadudu kama Minyongoro' (earth warm) na "igunyo" (cut warms). Another problem experienced here are diseases and pests during rainy season as well as dry season. (Giving examples the participant continues) "diseases like 'muthingitho" bacterial wilt (showing an example of a sick plant as shown in plate 3.) and other diseases that we don't know their names spread fast during long rain seasons affecting a large portion of land in case the sick plant is not uprooted. The symptom of this disease is wilting of potato plant (showing a sick plant in her farm) and produces potatoes with black sport in their scars. Moles also increases during rainy seasons causing a lot of damage on potatoes and when rains reduce potatoes are damaged by pest like earthworm and cut worms.* ***(FGD1, chairperson)***
>
> *Viasi nyingi zenye tulikuwa tunapanda kama; Ngorufu, desiree, meru, na Nyayo ziliisha juu zilikuwa zinagonjeka sana na hata zenye tunapanda saa hii kama Shangi, Dera mwana, Tigoni na kanyoni ni nyepesi sana na magonjwa pamoja na wadudu huziharibu sana. Most potato variety that we use to grow like; Ngorofu, Desiree, Meru, and Nyayo are no longer there because they were easily affected by pest and diseases and even the varieties we are planting today like; shangi, Dera Mwana, Tigoni and Kanyoni are very soft potatoes and they are highly destroyed by pest and diseases. (**FGD3, male participant**)***.***

This finding is contrary to Kaguongo *et al* (2008) findings in their study on farmer's practices and adoption of improved potatoes variety in Kenya and Uganda, who found that the shift on Irish potato variety of preference was market demand and premium prices it attracted and they gave example of potato growers in Meru and Central

Kenya who stuck on growing kerr's pink variety due to market demand despite of its' extreme susceptibility to late bright disease.

Although there were no statistical evidences to prove such claims, an in-depth interview with the agricultural extension officers reported that several diseases affecting Irish potato in Ndaragwa such as Early and late blight, black leg and soft rot and bacterial wilt thrives well in cool and humid environment and they are easily spread out through run- off water. The officer further points out that pests like Aphids, potato tuber moths, cut warms and cyst Nematodes are increasing in the area because they thrive well in warm and dry climates. She however said that currently farmers are using a lot of chemicals to control diseases but for the case of Bacterial wilt, they still have a big challenge for there are no any chemicals to control it and the only advice they give to farmers is to uproot the affected potato plants at the early stages before it spread widely.

These findings are in line with those of Kaguongo *et al* (2008) who found out that late blight is most damaging in areas with high rainfall and low temperatures although farmers did not perceive the disease as a major limitation since they said they could control it using fungicides unlike the bacterial wilt which farmers considered as more catastrophic, since it has no chemical to control it once it strikes. Kaguongo *et al* (2008) also found that in Kenya farmers don’t know how to control the disease and no potato variety was considered to resist or tolerate bacterial wilts.

An extensive interview with a KII (female participant), reported that farmers in the area experience bacterial wilt disease every season and because it is not treatable, they are now trying to use their indigenous knowledge like applying ash, uprooting the sick plants and burning them to control the disease. The participant showing sample of already affected crops as shown in plate 3 and 4 lamented that they have been complaining and calling for the government intervention to help them but nothing has so far been done. The study finding compares favorably with Muthoni *et al* (2013) findings in their study on potato production in Kenya where they found that 15% of the farmers interviewed manage bacterial wilt disease by uprooting and throwing the wilting plants and their tubers in a hole and scooping the soils where the effected plants were and immediately apply two handful of ash on the remaining soils to burn the bacteria.

Plate 4.3: Showing A Farmer Lamenting The Effect Potato Diseases On Her Farm

Source: field work 2019, in Shamata

Plate 4.4: A potato plant affected by bacterial wilt

Source: field work 2019

Apart from frost bite, pest and diseases 56.3% perceived rotting of potato tuber in farm during high rainfall. The same information was shared during a key Informant interview, where the respondent (farmer 4) said that high rainfall cause flooding or logging which result to high rotting of tubers especially in lower zone. The participant also reported that, they harvest a lot of spoiled tubers and others are damaged through cuts when harvesting which result to high post-harvest rotting since tubers are stored with mud hindering proper sorting of the spoiled one. This corroborated with previous study by Njenga *et al* (2013) where they found that water logging resulted to rotting of crops and seeds thus leading to poor crop performance and yields. A report by KHCP (2013) also indicated that towards the end of the season when the potato plants begin to yellow and leaves starts drying, the amount of water should be reduced gradually as the crop water requirement reduces and the wet condition late in the season contributes to tuber rot in the farm and in storage.

Another effect that was highly perceived by the respondents in Table 4.19 is food shortage with a total of 41.4% where 23.3% perceived food shortage during low rainfall, 15.2% in high temperature while 2.7% in Low temperature. A discussion during the FGDs revealed that the frequent occurrence of drought condition and increase of temperature in recent years has been causing food shortage in the region. One of the participants in the focus group reported food shortage according to the majority of the people in the area means a shortage of the main stable food which is Irish potatoes from their own farms and not necessarily unavailability in the market. Poor production was also indicated by 26.4% of the respondents with 12.3% indicating during high temperatures, 10.5% in low rainfall, 1.8% in high rainfall while 1.8 in low temperatures. During focus group discussion, one of the participants reported that the amount of potato harvested is reducing because in rainy season, besides rotting of tubers there is poor harvesting since most potato tubers are left under the soaked soils and they later germinate as wild potatoes. The participants further revealed that poor production is also cause by increased drought conditions in the region which do not only affect production but leads to food shortage as well. Another participant however commented that poor production is also affected by other factors such as soil fertility, poor seed, market prices, lack of limited agro-chemicals like fertilizers and lack of herbicides and pesticides.

Further to this, respondents also perceived Poor crop germination (30.6%), poor quality of tubers (33.0%), wilting and drying of crops (25%), crop failures (22.5), and slow growth (22.3%). However, few of the respondents (6.8%) perceived fast growth of Irish potatoes while (1.6%) perceived good and high yields.

According to the information shared by the key informant (Agricultural Officers) Irish potatoes in the region have reduced in terms of quantity and quality. They reported that today farmers are not proud of their production; because either they harvest few bags of potatoes or small sized tubers which they have nicknamed "tuquellea" meaning small birds knows as "Qeulles". The same information was vividly captured from the FGDs that:

> *Siku hizi tunashangaa sana, shaangi yenye tumekuwa tukipanda kwa miaka sasa imebadirika sana, inamea na kuwa mreefu ukiiona kwa juu unafurahia lakini ukiichimba tuviazi ni tudogo tudogo twingi hadi tunatuita 'tuquelo"(this days we are surprised shaangi (potato variety) that we have been planting over years have greatly changed, it germinates and grows so tall in that when you look at it you become happy but when harvesting, the potato are many but very small in size till we are now calling them small quelea birds.(* ***female participant FGDs 1, Githungushu farmers field group).***

The expression supports the findings by by Muthoni *et al* (2015) and Borah *et al* (1962) who say that at temperatures beyond 17^0c during the day inhibits potato yields through overall reduction of plant development while high night temperatures are much more deleterious to the formation of tubers than the day temperatures. They also found that at lower temperatures of 15^0c tuberisation was delayed in one week and at high temperatures of 25^oc tuberisation was delayed by three weeks.

The officer however reported that besides change of climate, the Irish potato production in Ndaragwa is also affected by uncertified tuber seeds, soil quality, lack of proper guideline on potato production, inadequate agricultural extension officers, and high cost of input. She reported that decline in potato yields is due to lack of clean seeds because many farmers just take potatoes they harvested the previous season and use them as seed and incase such potatoes are affected, then the disease spreads to other parts of the farm previously not affected. This compares favorably with Nderitu *et al* (2014) who reported that Kenya produces less than 1% of the national certified potato seed demand and because of this, the certified seeds are highly priced and are beyond reach of most small-scale farmers, therefore forcing farmers to plant seeds from informal sources such as farm-saved (self supply), local markets or neighbors. The use of seeds from informal sources has led to low yields, poor quality produce, and spread of pests and diseases.

Karanja (2013) found that Potato farmers in Oljoro-orok division face several challenges including rainfall variation, lack of clean seeds, soil degeneration, diseases, high cost of farm inputs and inadequate field officers. However, Bulus *et al* (2017), point out that despite that other factors also affect production of Irish potatoes, climate change and variability have more adverse effects for it is measured in terms of crop growth, availability of soil water, soil erosion, incidences of pests and diseases and decrease in soil fertility.

4.6 Practices and Technologies Related to Climate change Adaptation on Irish Potato Production among the Community in Ndaragwa

The concept of resilience offers a better entry point to analyze adaptation to climate change by building buffer capacities, enhancing self-organization as well as the capacity to learn and adapt (Ifejika, 2013).

To enhance resilience on climate change and variability and reach maximum agricultural potential, every stakeholder including the government, agricultural extension officers and farmers should vigorously pursue, adopt and engage in adaptation strategies that will not only solve issues of food insecurities but also mitigate climate change causal effects. According to Freyer (2014) and IPCC (1994) on perception and ability to adapt to climate change, both mitigation and adaptation should be adopted to respond to extreme changes, where mitigation embraces responses that deals with the cause of climate change rather than impacts while adaptation deals with impacts rather than the cause.

This section presents the findings from the respondents on the adaptive capacities and strategies to effects of climate change and variability. The study showed that none of the respondents indicated how to mitigate climate change that contribute to reduction and sequestration of global green house gas emissions, although they have embraced several adaptation strategies which according to FAO (2001) represent the best coping options against agricultural output reduction and improve livelihoods of small-scale farmers.

The results in Table 4.19 show that 82.1% are using several coping mechanisms to adapt to climate change and variability while only 17.9% have not yet changed their farming system to adapt to climate change. This show that the level of adapting to climate change has increased compared to some earlier studies. For example, Fosu-Mensah *et al* (2010) in their study on farmer's perception and adaptation in Ghana found that only 44.4% indicated the adoption of some adaptation strategies. The high adoption of adaptation strategies in the current study is attributed to high perception of climate change impacts to farmers as indicated in the previous section where 95.5% perceived changes in climatic condition. This finding implies that farmer's awareness on climate change and variability improves their level of adaptation. The finding is in line with Marshall *et al* (2013) in a study on climate change awareness and enhanced adaptation who found that farmers with a higher awareness of climate change and variability tend to have higher adaptive capacity. In another study on adaptation of farmers in Bahir Dar, Ethiopia, Legesse (2013) found that farmer's ability to adapt to effects of climate change was mainly influenced by their knowledge and perception on climate change. In contrary, Smither *et al* (1997) said that being aware of climate change does not necessarily imply recognition of the need to adapt; he found that despite some farmers' awareness of climate change the use of adaptation strategies was very low.

Table 4.19: Apply Coping Mechanism to Adapt Effects of Climate Change

		N	%
Do you apply any coping mechanism to adapt effects of climate change?	**Yes**	313	82.1
	No	69	17.9
	Total	**383**	**100**

The discussion in 4.2.1, show that rainfall and temperature in Ndaragwa Agro-ecological zone has been varying as characterized by change in rainfall pattern, late onset and cessation of rains, increased incidences of drought and increase incidences of frost. This is a serious threat to Irish potato production and it is leading to crop failure and reducing production. In this view therefore, the respondents in the region have various responses to adapt to effect of climate change and the responses from the household were summarized in Table 4.20 below.

Table 4.20: Coping Mechanisms Applied to Adapt to Effect of Climate change

Adaptation	High Rain %	High Temp %	Low Temp %	Low Rain %	Total %
Growing varieties that Mature faster	8.2	64.8	19.0	31.8	31.0
Planting drought resistant Crops	13.4	21.5	17.5	39.2	22.9
Changing planting dates	60.7	56.7	84.8	57.9	65.0
Irrigating potato farms	26.8	21.5	12.1	37.7	24.5
Focus on non-farming Activities	1.3	41.7	22.8	8.1	18.5
Use of inorganic fertilizers/Use of chemical	44.5	15.9	19.0	70.3	37.5
Apply soils and water	22.8	9.4	10.6	9.4	13.1
Conserving mechanism Practice Mixed farming	99.9	71.6	73.1	83.7	82.1
Moving to wet river banks	1.3	-	-	-	0.3
Livestock keeping	93.3	82.5	99.9	42.0	79.4
Water harvesting for Irrigation	2.5	-	-	-	0.6
Abandon potato farming	6.6	2.5	1.3	6.6	4.3

From the findings Table 4.20, it is clear that farmers have been using several coping mechanisms to adapt to effects of climate change. From the study findings, 82.1% of the respondents' practice mixed farming. This implies that most farmers have diversified their crop enterprises by shifting from mono-cropping to mixed farming. The same information was well captured from the FGDs where a male participant said that:

> *"Mashamba zenye tulikuwa tunapanda viazi pekee ziliisha, kwasababu kwa miaka kadhaa iliyopita wakulima wameumia sana juu ya kutegemea viazi pekee kisha barindi ya kuchoma viazi inamwagika au kiangazi na kumaliza kila kitu kwa shamba, sasa inabidi tunapande viasi, minji, maharagwe, matunda na mboga pamoja ili hari ya hewa ikibadirika kunazile kidogo zinabaki na kupunguza njaa.(lands that we use to grow Irish potato alone are no longer there, because in several years that have passed, farmers have suffered a lot for they were only depending on potatoes which is commonly affected by frost*

> *bite and drought destroying the whole farm, this therefore has led us to plant potatoes, peas, beans, fruits and cabbages together so that when climate changes the few resistant variety that will remain can reduce famine (**male participant, FGDs 3).***

These expressions imply that planting variety of crops with some for long seasons and others short seasons variety will reduce problems of food insecurity as well as maximizing land use through mixed farming.

An in-depth interview with an agricultural officer also reveals that, they have been training farmers to maximally use their land through intercropping and agro-forestry together with keeping dairy animals within the same land to minimize problems of famine. This finding is in line with Karanja *et al* (2014) who found that crop diversification and off-season approach are the major coping mechanisms applied by farmers in Ol joro-orok Kenya. In another study in Mbaisi (2014) in a study on effect of climate change on agricultural production in Kenya indicates that increasing agricultural biodiversity through crop diversification has proved to be a key livelihood strategy for coping with changing and more challenging environmental conditions in drought prone areas.

The findings also reveal that livestock keeping is practiced as a way of coping with changes in climate. Up to 79.4% of the respondents indicated that they are keeping dairy cows, sheep, Goats and poultry. This was also captured during an interview where farmers said that keeping animals especially dairy cows is easier compared to farming in an area that experiences high cases of drought. The finding is supported by a study done by Monica (2013) who found that dairy farming help farmers to cope better with climate change and variability. In an earlier study, Ngige (2003) also found that with cases of climate change and variability threatening agriculture especially in arid and semi arid lands, dairy farming stand to show great potential for the community. According to Yirga, (2007) in a study on dynamics of soil degradation in South Africa, keeping of livestock is having an asset that could be either used for production or for economic gains therefore having a significant role in adopting suitable adaptation measure to combat climate change.

On whether they are changing planting dates, 84.8% of the respondents indicated it as a way of coping with climate change during low temperature, 60.7% during high rainfall, 57.9% during low rain while 56.7% change their planting dates during high temperature. Through the key informant interviews it was established that farmers used to plant their potatoes before the onset of rains because the rains were almost certain starting on fifteenth of March every year, however, the rainfall trends have been changing in that it is no longer predicable and a time it delays up to May affecting farmers who planted in dry season and forcing them to re-plant twice or even thrice for only those who can afford hence reducing production. In support of this, the agricultural extension officer pointed out that, they use to advice farmers to plant earlier before the rains but nowadays they are advising farmers to plant when the rains have started and the soils are well soaked to enable germination within a week. The officer further said that, due to change in planting time, the growing seasons have changed from three seasons February to June, August to October and November to February in to two seasons April/May to September and September to January. These findings are consistent with the findings of a research done in Switzerland by the Info resources (2008), who found that farmers in Bolivia are experiencing drastic shorter potato growing periods due to late onset of rains which sometime start on December rather than October leading to changing planting dates and seasons and also affecting the bulking span due to early maturity hence poor potato quality. Elsewhere in Kenya, Stefanovic (2015) found that farmers in Laikipia prefer planting late unlike in the past for they are insecure when to expect the onset of the rainy seasons. However, through an elderly key informant, it was revealed that they are relying on local traditional knowledge to predict when the rains will start as he complained that the information they receive from the meteorological department is not reliable. The key informant revealed that some of the most widely relied indicators are timing of trees fruiting seasons, water level in streams and ponds and the migrating birds and insect's behavours. The respondents also said that some farmers observe the movements of winds and clouds which help them to make their predictions of the planting seasons.

Further, the respondents indicated the use of inorganic fertilizers and chemicals as another adaptation mechanism used by Ndaragwa farmers. In general, 37.5% use several different chemicals in terms of fungicides and insecticides, with 70.3% using them during low rainfall, 44.5% during high temperatures, 19.0% during low temperature while 15.9% during high temperatures. This was also triangulated during the focus Group discussions where discussants confirmed that they are using a lot of chemicals in their farming systems. For instance, a female participant said that;

> *"ukulima wa viazi bila kutumia dawa na fertiliza haiezekani tena, siku hizi magonjwa ya viazi kama Muthingitho, P.CN, wilt na wandudu wameongezeka sana, kitambo tulitumia jivu kupunguza magojwa na wadudu lakini haifanyi tena na inatulazimu tuspray madaya ya kila aina kwanza wakati wa mvua (growing Irish potatoes without using chemicals is no longer possible, these days diseases like potato bright, Potato Cyst Nematode, potato wilt and pests are so common and initially we use to apply ash to control them but its no longer working and we are now forced to spray potato plants with various chemicals especially during rainy seasons* ***(Female Participant, FGDs 2)***

In support of this expression, the agricultural extension officer points out that, farmers are using a lot of fertilizers, herbicides, fungicides and pesticides. Giving examples of the commonly used chemicals, the officer mentioned Ridomeal, Master and Super grow which are both protective and curatives. Other studies done earlier corroborate this finding for example, Monica (2013), Kaguongo *et al* (2008) and Olanya *et al* (2006) reported that Irish potato farmers are using strategies like spraying herbicides, accarides, fungicides and insecticides as the best methods to control both pests and diseases.

The household survey revealed that growing variety that mature faster and planting drought resistant crops were other adaptation strategies that enhance resilience on climate change. Of the farmers interviewed, 31% and 23% respectively saw both strategies as opportunities to adapt to climate change. However, through the key informant, it was revealed that farmers in Ndaragwa do not have access to this resistant variety because majority replants the potato using the seed they have harvested locally. In support of this finding, the agricultural officer confirmed that most farmers grow their local variety and this reduces production because if a potato variety is not changed within a span of 5 years it keeps on depreciating and depleting same nutrients from the soils and they are also affected by the same pests and diseases. The officers also said that they have been training farmers to keep changing potato varieties and planting certified seeds that mature fast and are resistant to high temperature and water scarcity but the main challenge is lack of finance to buy the seeds.

Irish potato is grown in several different regions, but it is adapted to temperate regions with temperatures ranging between 15^0c to 18^0c and soil ph of 5.5 to 6.0 (KENFAP, 2013). Successful Irish potato production depends on the right choice of potato variety, which will develop mature tubers within the length of the growing season. It is highly sensitive to high temperatures as well as low temperatures which lead to frost that cause severe damage to the crop when temperature drops below 0^0c. Potato is believed to have the best produce at its optimum temperature of 17^0c. Unlike other crops variety for example maize which grains at daily temperature of about 20^0c, Irish potato is affected by both daily temperatures and night temperatures. A combination of high temperatures and long days only favour assimilation of carbon above the ground vegetative plants leading to increase in plant height and reduced tubers while the minimum night temperatures assimilate carbon to the tubers enlarging tubers hence increase productions and tuber quality. This implies that climate change and variability is affecting potato production as temperatures keep on increasing and will continue influencing the schedules of potato sowing, flowering and tuberization.

A few of the respondents (24%) especially those living near small streams indicated irrigation as a coping mechanism to climate change and variability. In their report, they said that they have been growing Irish potatoes under irrigation and although the cost of production is high, they have always harvested in all seasons. These findings were in line with Monica (2013) who found that 15% of the respondents reported irrigation as an adaptation strategy to climate change and variability. Through a discussion with Marwai farmers' field business school, discussants reveal that irrigation can be a potential adaptation option if only the government can drill for them several boreholes that can supply water in the region. They also pointed out that majority have not embraced irrigation because water scarcity is a major problem in Ndaragwa, and even for those near streams, water is not reliable for the streams dry up immediately when there are dry seasons. These findings were consistent with the research findings by Stefanovic (2015) who found that irrigation as an adaptation method was less frequently mentioned, as farmers said that they often rely on rains and on low construction of water storage which could not sustain irrigation system. A research by Mbaisi (2014) also recommended that the Kenyan Government should provide irrigation infrastructure to make maximum use of available water to benefit the local community especially those in semi arid lands, through construction of dams which in turn will be used for water harvesting during heavy downpour and will be used for crop production as well as providing water that will bridge the gap between wet and dry spell.

Due to Unpredictable rainfall, Irish potato production is expected to reduce more which is a threat to Kenya's food security being the second most consumed food crop after maize. To combat the situation, irrigation farming systems are highly recommended both low-cost technologies and public irrigation schemes especially in the arid and semi arid regions like Ndaragwa, this will have high potential to transform the small-scale farmers into intensive food producers which will secure food security in the country (FAO, 2015).

Focusing on non-farming activities was also identified as an opportunity to adapt to climate change. Through a discussion with the FGs, the discussant revealed that some farmers are quitting farming activities and venturing into business activities which they claim that the profit margin is higher than that of farming.

Other measures undertaken by farmers include applying water and soil harvest, abandoning potato farming and moving near wet river banks. Of this, 13% indicated that they are applying water and soil conservation methods, 4.8% abandoned potato farming while only 0.3% shift near the wet river banks.

These findings affirm that farmers in Ndaragwa are using several coping mechanisms to counteract the effects of climate change and variability. However, the study revealed that some of the effects of climate change like frost bite have no cure and once it strikes, farmers stand at the mercy of God. This was captured from the FGDs where respondents said that, frost bite is the worst of all because they don't know how to control it and that they have tried using different chemicals which are not effective at all. However, With devolution, Nyandarua county government is trying to improve on potato production by coming up with Nyandarua County Potato Strategies that is aimed at guiding the farmers and the development partners in aligning development and increasing potato yields in the county by at least 40% and income of potato farmers by at least 20% by December 2021 through participatory evaluation of potato breeding lines, variety demonstrations, improvement of production, promotion of mechanization and irrigation technologies, and improvement of pre and post-harvest management of potato produce, market access, enacting and enforcement of policies and regulations MoA, (2017).

CHAPTER FIVE

SUMMARY OF THE FINDINGS, CONCLUSION AND RECOMMENDATIONS

5.0 Introduction

This chapter presents the summary of the findings, draw the conclusions and make the necessary recommendations including suggesting areas of further study**.**

5.1 Summary of the Findings

The study established that although agriculture is the backbone of the Kenyan economic growth as well as food security, the sector is deteriorating and becoming progressively less productive. The decline in agricultural activities is associated with several factors, climate change being one of the most risks on the lead line. From the study, it was revealed that climate change is real and is happening, with the growing evidences of such indicators like floods, extreme high and low temperature, famine and drought and it affects Irish potatoes farmer directly or indirectly. The study also reveals that, several studies have been carried out focusing on effect of climate change and agricultures, with few narrowing down to Irish potato but none to my knowledge has focus on effect of climate change on Irish potato production in arid and semi arid regions yet the regions are more vulnerable to climate change. The study also reveals that despite the increasing rate of temperature due to climate change, frost bite is still a common challenge affecting Irish potatoes in Ndaragwa almost every year leading to low production and the living standards of that community. The study further reveals that Irish potato is the second most consumed food crop in Kenya and with the risk associated with climate change, there is high risk on potato production which is more sensitive and adapt well in cool climates. Such situations therefore necessitated dire need for this study.

From the relevant reviewed literature, the current study reveals that climate change is affecting almost every sector including economic, social and environmental with agricultural activities being the most affected because it entirely depends on the weather elements for higher production. This has intensified most studies although there remain some critical gaps identified in this study. For instance, the study established that arid and semi arid lands are largely associated with pastoralists, down looking the small-scale farmers who are as well affected by climate change and variability. Secondly, there is generally little information on the public awareness on climate change as a cause of frost bite, despite its regular occurrences in several regions in Kenya. Thirdly, climate change adaptation requires building resilience with all stakeholders participating and not only considering farmers coping mechanisms. However, to mitigate and adapt the risks of climate change also requires integration of the local knowledge which will only be achieved when farmers perceive the effects of climate change and lastly, effect of climate change on agriculture requires spatial/areal and system specifics rather than spatial generalization because perceptions on climate change depends on specific location and agricultural activities carried out. This study therefore set to fill the gaps through the following objectives: To determine the nature of climate change and variability in Ndaragwa, To establish the relationship between Irish potato production and climate elements in the region, To determine peoples' perception on the effect of climate change and variability and to analyze the practices and technologies related to climate change and variability adaptation.

The study used scientific research methods, techniques and tools for obtaining data that help to achieve the above objectives. Both primary and secondary data were used where secondary data was obtained from published and unpublished sources, maps, books, development plans, journals and other relevant academic sources. The primary data was through a field survey that was collected with the help of questionnaires and interview guides while data on potato production and climate was obtained from the ministry of agriculture in Nyandarua county and Kenya meteorological office in Nairobi. The data was later analyzed using both quantitative and qualitative data analysis techniques. In Quantitative techniques simple descriptive statistics such as frequencies, percentages and means were used while data on climatic parameters and potato production were further subjected to inferential statistics using correlation analysis to identify the relationships between study variables while content analyses was used for qualitative data and presented in form of tables, figures and plates.

The study established that despite the people perception that rainfall in Ndaragwa has been reducing, the study findings show a general slight increasing trend of the annual rainfall. The increase is highly contributed by the short rain seasons which shows an increasing trend throughout the years unlike during the long rains season where some years it shows a reducing trend or remain constant. An erratic rainfall pattern was observed showing that the region receives rainfall below the average most of the years with the peaks noticed in the months of April and August, where the August peaks coinciding with the harvesting seasons leading to poor road networks that hinders transportation, increased cases of potato rotting and hindering easy harvesting activities causing most tubers to be left under the soaked soil.

The study revealed that rainfall MAM season has slight decreasing trend while rainfall during the month of SON shows a general increasing trend over the entire period. The study also depicts a rapid decreasing trend in the month of June and July. This coincides with the flowering and bulking period which has resulted from late planting dates that is influenced by late onset of rains, affecting Irish potato production that entirely depends on the onset of rains and the general distribution of rains throughout the growing seasons. Climate change and variability altered the rainfall duration and intensity leading to delay in the onset which influences the planting dates. This decrease in rainfall in the month of June and July occurs at the critical stage having adverse effect on production.

Further, the study revealed that the rainfall has a significant variation for both the annual and seasonal rainfall. The annual trends range from +362.6 in 1998 to -344.5 in 2000 and the seasonal rainfall ranging from +214.4 in 2010 to -214.4 in 2000 in long rains and +191.1 in 2008 to -99.5 in 2018. This also bring about variations in Irish potato production for instance in 2000 and 2017 where low rainfall was recorded, the total yield was 900 tons and 1,048.05 tons respectively while in 2001, 2007, 2008 and 2013 when rainfall was high and well distributed the total potato yields were 8,111 tons, 17094 tons, 14,220 tons and 8,432.50 tons respectively. This variation leads to unpredictable weather pattern destabilizing farmers plan and decision, therefore accurate information from the meteorological department is required to help farmers make informed decision on when to prepare their farms and plant their seeds.

The study further found that, well distributed rainfall throughout the year increases Irish potato production however; cases of frost bite, water shortage and drought were highly reported in Ndaragwa. This revealed that, erratic rainfall sometimes leads to re - ploughing and re-planting which increases the cost of production to small scale farmers. Rainfall variability was highly associated to high damage of Irish potato through rotting as well as increased cases of pests and diseases like bacterial wilt, early and late bacterial bright, blackleg and soft rot, warms and potato cysts nematodes (PCN).

Finally, it was established that there has been changes in seasonal rainfall which is becoming more unpredictable. The onset and cessation of rains has changed, the onset of rains is regularly delaying from its normal pattern on mid-march extending up to April or May, leading to changes in planting dates that is now resulting to variation in yields. Due to this late onset of rains, farmers are no longer planting during the dry season for the fear of losing their seeds that fail to germinate in unpredictable rainfall.

Analysing temperature of the region, it was revealed that annual and seasonal temperatures in Ndaragwa agro-ecological zone have increased. The study shows that the temperatures have been increasing in both maximum and minimum temperatures. The trend also shows that temperatures are high during the first half of the year with the peaks being noticed in the month of February and March except the months of July and August which record the lowest temperatures. Further, despite the increasing trends in temperatures, it was established that the range between maximum temperatures and minimum temperatures is wide, implying that the temperatures recorded at night are too low and sometimes it drops below the freezing points which leads to frost, a common challenge that has been affecting production of Irish potatoes in the region.

From the findings, Irish potatoes adapt well to cool climates and therefore increases in temperatures in the region may have both blessings and curses. Temperatures influences the growth and development of the crop in that when temperatures rises above the plant optimum temperatures of 18^0c, it hinders proper tuberization of potatoes and lead to increase in height of vegetative part of the crop due to high assimilation of carbon on the upper part while the assimilation of carbon on the lower part that depend on night minimum temperatures is limited. High temperature will also increase evaporation, reducing soil moisture and increase demand and completion for water available for the crop, reducing crop production. On the other hand, the study reveals that increase in minimum temperatures will reduce cases of frostbite which regularly leads to total crop failure in the region.

The study also reveals that, climate change intensity causes various risks in Ndaragwa including drought, frosts, floods, heat waves, torrential rainfall and hails which affects Irish potatoes through cases of poor germination, rotting of potato tubers, increased pests and diseases, frost bite, food shortages, poor quality of tubers, wilting and drying of crops. It's due to these effects therefore, that the respondents revealed to have been using various mechanisms to counteract effects of climate change and variability. Among the adapted strategies used by farmers includes practicing mixed farming, livestock keeping, changing planting dates, growing potato varieties that mature fast, irrigating potato farms, using inorganic fertilizers, use of chemicals and planting drought resistant crops.

5.2 Conclusions

The study shows that climate change and variability has occurred in Ndaragwa evidenced by variation in rainfall and temperatures. Rainfall shows slight increasing trend while temperature shows a drastic increasing tread. The area also depicts a unique behavior with the rainfall increasing during the short rain season while in the long rains is either reducing or remain constant in some months of the year. Rainfall in the region also depicts clear variation, most of the months, the rainfall received is below average leading to extreme events of drought, water shortage and famine, this has made Ndaragwa agro-ecological zone to be categorized among the arid and semi arid lands of Kenya**.**

From the study, it is also clear that temperature of the region is increasing in both minimum and maximum temperature; this comes with both positive and negative impacts. The increasing trend in minimum temperature implies that cases of frost bite in the region will gradually reduce and therefore potato farmers will be relieved from this highly destructive event that have no cure. However, with the increasing trend of maximum temperature, the crop optimum temperatures of 18^0c will be surpassed influencing the production of Irish potatoes which adapt well in cool climates. The increasing of temperature also hinders tuberlisation of potatoes leading to tall plant with very small tubers called by the respondents “small quelea” it also leads to high evaporation rates reducing the availability of moisture in soils which is very important for potato production.

The study concludes that the level of awareness on climate change and variability among the respondents has increased and they are able to describe the phenomenon from their own local experience. The information is accessed through media, farmer associations, and traditional methods like observing the sky and certain animals’ behavior, agricultural extension officers, internet and through attending some agricultural training.

It was also concluded that, adverse risk cases related to climate change and variability are commonly experienced in Ndaragwa agro-ecological Zone including: drought, frost and floods. These risks were associated with the common effects of climate change and variability experienced including frost bite, increased cases of pests and diseases, crop failure, poor germination, poor quality of tubers, rotting of potato farms and food shortage.

Further, the study reveals that Irish potato crop is a highly susceptible to pests and diseases, which thrives well in warm temperatures and humid conditions, this implies that with increasing temperature and rainfall more incidences of pest and diseases will be recorded and therefore increasing the cost of production which will see most farmers abandoning potato production as indicated by several. As a result, issue of food insecurity will increase as the study reveals that Irish potato is the second largely consumed in Kenya.

The study also concluded that there is a strong positive relationship between rainfall and irish potato production in all seasons and as rainfall amount increases, potato production also increases and vice versa. The relationship between Irish potato production and mininum temperature reflected a weak positive relation while maximum temperatures resulted to a moderate negative relationship indicating that as maximum temperature keep on increasing per unit, the production of Irish potatoes will be reducing.

Finally, the study reveals that farmers are practicing several adaptation strategies including mixed farming, livestock keeping, changing the planting dates and also irrigating potato farms. However, the study calls for building resilience to climate change and variability through mitigation and adaptation. Farmers should be prepared for any climate change related risks, desire/commited to survive no matter the risks, Adaptability, gaining experience, collecting and coordinated response by all stakeholders and enhancing household adaptive capacity.

5.3 Recommendations

The study reveals that climate change and variability has occurred in Ndaragwa Agro-ecological zone as evidenced by unreliable rainfall, late onset and cessation, drought and floods that lead to changing planting dates, reploughing and replanting hence increasing the cost of production. It is for this reason that the study recommends that the meteorological department should strive to provide accurate and timely information, to help farmers make informed decision on when to prepare and plant the seed.

The findings indicated that the area prone to adhesive frost bite that originate from cold air of the Aberdare ranges moorland through the lands leading to total crop failure since there is no preventive or curative chemical once it falls. This calls for the need by the government both national and county government to promote crop insurance to Irish potato producers, to protect them against the total loss of their crops due to either frost bite, drought, floods or pests and diseases.

It has been established that Irish potato are very sensitive to pests and diseases which have been highly associate to changes in climate. It was also established that the spread of pests and diseases is even increasing because farmers tend to use a potato variety for many years because they cannot afford to buy new varieties that might be resistant. This study therefore calls for the National Potato Council of Kenya (NPCK) and Kenya Plant Health Inspectorate Services (KEPHIS) to provide potato certified seeds at an affordable price to small scale farmers.

Further, the study recommends that the government should employ many Agricultural extension officers who train farmers on modern ways of farming. This is because the study established that farmers are not trained on the best methods to adapt to effects of climate change and variability because the officers are few and can only train farmers who join field schools.

The study also established that though most farmers have perceived climate change and variability in the region, they are not able to apply some of the adaptation mechanisms like irrigation due to shortage of water. This calls for the county government in corroboration with the National government to drill boreholes to farmers especially those in arid and semi arid regions to enable them reach the potentials of agricultural activities.

Finally, the study recommends public campaigns to create awareness on both climate change mitigation as well as climate change adaptation. This will only be achieved through collective actions where all stakeholders should participate and develop policy that promote building of resilience among the Irish potato farmers in Ndaragwa agro-ecological Zone and address specific regions as different farming system are affected differently by climate change.

5.4 Area for Further Studies

The study was limited to adaptation strategies. Further research should focus on challenges and the effectiveness of the adaptation strategies.

The study focused on impacts of climate change on small scale Irish potato farmers. Further research should be done on the effect of climate change on large scale farmers to compare the results.

Lastly the study focused on climate change related risks including diseases, however further research should be done specifically on climate change in relation to Potato Cyst Nematode (PCN) on potato production, a recent and more destructive disease in the region.

REFERENCES

Abdi, N. (2004). *The Influence of Rural Logistics and Rural Transport Costs On Farm Income And Poverty In Kenya: The Case Of Kisumu And Nyandarua Districts, Kenya*

Adeniyi M, Ogunsola O., Nyamphas E, & Oladiran O. (2009). Food Security Measures During Uncertain Climatic Conditions in Nigeria. University of Ibadan, Ibadan, Nigeria. *African Journal of Food Agriculture Nutrition and Development* 9, 652-677

Adger, W. N., Huq, S., Brown, K., Conway, D., & Hulme, M. (2007). Adaptation to Climate Change in the Developing World. Progress in Development Studies No. 3. Pp 11-17

Alastair, M. (2010). The Concept of Resilience, Understanding its Origins, Meaningand Utility. A straw man paper and a Director of the Torrens Resilience Institute, Adelaide, Australia.

Alemaw, B.F., Onema, J.M.K. and Love, D. (2013) Regional Drought Severity Assessment at a Basin Scale in the Limpopo Drainage System. *Journal of Water Resource and Protection*, 5, 1110-1116.

Allen, C. R. Gunderson, L., Johnson, A. (2005). The use of discontinuities and functional groups to assess relative resilience in complex systems. *Ecosystems* 8:958-966

Alessandro, S., Caballero, G., Simpkin, S., & Lichte, J. (2015). *Kenya Agricultural Risk Assessment, Agriculture Global practice Note*. World Bank Group.

Anithakumari, A.M., (2011). *A thesis on Genetic Dissection of Drought Tolerance in Potato*, Wageningen University. Wageningen.

AshaLatha, M., Munisamy, K.V., &Bhat, A.R. (2012). Impact of Climate Change onRainfed Agriculture in India. A case study of Dharwad. *International Journal of Environmental science and Development* vol.3, no.4

Babbie, E., (2010). *The Practice of Social Research*, 12th ed. USA, Wadsworth Cengage Learning.

Bernard, S., & Samuel, J. (2001). *Environmental Health Perspective.* A.Grambsch K.L Edi and Romieu at https://www.ncbi.nlm.nih.gov/

Binam, J.N., Tonye, J., Wandji, N., Nyambi, G., and Akoa, M. (2005). Factors Affecting the Technical Efficiency among Smallholder Farmers in the Slash and Burn Agriculture Zone of Cameroon. *Food Policy*, 29:531-54

Borah, M.N., & Milthorpe, F.L.(1962). Growth of the potatoes as influenced by temperatures. *India journal of plants physiology.*

Bulu, H., Nimfa, D. (2017), Effects of climate change on Irish Potato farming in Plateau. A Study of North and Central Zones of plateau state Nigeria: *international journal of Economics, commerce and management*. United Kingdom

BBC World Service Trust, (2010). Kenya Talks Climate, The public understanding of Climate Change Research Report.

Blom-Zandstra, G., & Verhagen, J. (2015). Potato production systems in different agro ecological regions and their relation with climate change. Wageningen UR (University & Research centre) Business Unit Agrosystems Research.Netherlands

Bryman, A., (2008). Social Research meme hold. Pg 592, oxford University Press

Charles, L., Nathaniel, L., & Ryan, S. (2007). Climate Change Research Analysis, An interactive qualifying Project Report. Worcester Polytechnic institute

Center of excellence in Coral Reef Studies, ARC. (2015), Climate profound Impact on Marine Biodiversity.

Chinwe, I.S., (2010). Resilient adaptation to climate change in African Agriculture. German Development Institute. German

.

Cline, W.(2007.Global Warming and Agriculture, Washington, DC: Peterson Institute for International Economics at:https://www.imf.org/external/pubs/ft/fandd/2008/03/pdf/cline.pdf

Climate-data.org (2019). Ndaragwa weather and climate for every Month at: https://en.climate- data.org.

Coe, S.J., Deborah, M., Megan, M., & Friggen, S. (2011), An Assessment of Climate Change and the Vulnerability of Wildlife in the Sky Islands of the Southwesthttps://www.fs.fed.us/rm/pubs/rmrs_gtr273.pdf

Coumou, D., Robinson, A., Hare, B., Schaeffer, M. (2016), Climate Change Impacts in sub-Saharan Africa from physical changes to their local repercussions. Regional Environment change Research gate.

Cohen, L., & Morrison, K. (2007). *Research Methods in Education*. 6th Edition. London and New York: Routledge Taylor and Francis Group.

Cordula, W., Florens, E., & Kurt-Johannes, P. (2016). Climate Change Awareness and small holders-oriented Constraints and Opportunities in the Upper Rift Valley in Ethiopia

Dai, A. (2006). Recent climatology, variability, and trends in global surface humidity. Journal of Climate, **19**, 3589-3606, doi:10.1175/JCLI3816.1.

Darnhofer, I., Moller, H., Fairwealth, J. (2008). Farm resilience for sustainable food production: Aconcept Framework; University of Natural Resource and Aplied Life Science Vienna. Austria

Debashis, R. & Toma D.N., (2018). Small holders' farmers perception to climate change Impact on crop production; cases from drought prone areas of Bangladesh.

Dennis, S., Gedion, D., & Justice, B. (2016). Cocoa Farmers Perception on Climate Variability and its Effects on Adaptation Strategies in Suaman district of West Region, Ghana

Deressa, T. (2010. Factors Affecting the choice of Coping Strategies for Climate Extremes. Environmental and Production Technology Division. Discussion paper 01032

Demenke, G. (2014). Irish potato production in Doto Gene woreda, Southern region of Ethiopia.

Dinar, A., Mendelsohn, R., Evenson, R., Parikh, J., Sanghi, A., Kumar, K., McKinsey, J, &Lonergan, S. (1998) 'Measuring the impact of climate change on Indian agri-culture', World Bank Technical Paper No. 402, Washington, DC

Dixon, J., & Lindsay, C. (2015). Towards a Theoretical Grounding of Climate Resilience Assessments for Smallholder Farming Systems in Sub-Saharan Africa. Sustainability Research Institute, School of Earth and Environment, University of Leeds, Leeds LS2-9JT, UK; E-Mail: l.stringer@leeds.ac.uk

Elinah, K. (2016). Precipitation and Temperature Extreme in East Africa in the Past and future Climate.

Everlyne, B. (2015). Assessment of Impacts of Climate Change and vulnerability on foodsecurity in West Pokot County. Kenya

Fanen, T., & Dialekan, A. (2014). Perception, Knowledge and Adaptation as socio-economic Cost of Climate Change in Northern Nigeria.

FAO. (2001). World Agricultural Statistics, Basic Data Unit, Statistics Division. FAO, Rome, Italy.

Food and Agriculture Organization of the United Nation, FAO. (2005). Frost Protection: Fundamentals, practices and Economics. Rome Italy.

Food and Agriculture Organization of the United Nation, FAO. (2007). Climate change and foodsecurity. FAO, Rome, Italy

Food and Agriculture Organization of the United Nation (FAO, 2012), Fao statistical year book2012. Rome

Food and Agriculture Organization of the United Nation (FAO, 2013), Mortality among population of Southern and Central Somalia affected by severe food insecurity and famine during 2010-2012.

Food and Agriculture Organization of the United Nations (FAO, (2015), Scoping study on climate-smart agriculture in Kenya, Smallholder integrated crop-livestock farmingsystems. Mitigation of Climate Change in Agriculture (MICCA) ProgrammeBackground report.

Food and Agriculture Organization of the United Nations (FAO, (2015). Kenya's Tea sector under climate change; An impact assessment and formulation of a climate Smart Strategies. Rome Italy.

Food and Agriculture Organization of the United Nations Statistics Division (FAOSTAT, 2017) Kenya, Emissions –Agriculture total, March 30, 2017.

Food and Agriculture Organization of the United Nation (FAO, 2018), Kenya at a glance. At www.fao/Kenya/Fao-in-kenya /kenya-at-a-glance/en/

Folke, C., Carpenter, S. R., Walker, B., Scheffer, M., Chapin, T., & Rockström, J. (2010). Resilience Thinking: Integrating Resilience, Adaptability and Transformability. Ecology and Society, 15(4), 20. https://doi.org/10.5751/ES-03610-150420

Folke, C. (2006). "Resilience: The emergence of a perspective for social-ecological systems analyses", Global Environmental Change 16, 2006, 253– 267

Fosu, M.B., Vlek, P.L., & Mac carthy, D.S., (2009). Farmer's perception and adaptation to Climate Change. a case study of Sekydumase district in Ghana.

Fosu- Mensah, B., Vlek, P., Manschadi, A. (2010). Farmer's perception and adaptation to Climate Change. a case study of Sekydumase district in Ghana. Center for development Research; University of Bonn Germany.

Franke, C., Haverkort, J., Steyn, M. (2013). Climate change and potato production in contrasting South African agro-ecosystems. Assessing risks and opportunities of adaptation strategies. Department of Plant Production and Soil Science, University of Pretoria, South Africa.

Frumkin, H., Hess, J., Luber, G., Malilay, J., & McGeehin, M. (2008). Climate Change: The public Health Response. American Journal of Public Health 98(3) 435-445.

George, M. (2016). Effects of Climate Variability on output and yield of selected crops in Kenya.

Government of Kenya GOK. (2013). First county Integrated Development Plan 2013-2017. Kenya, County Government of Nyandarua

Government of Kenya GOK. (2012). Agricultural Sector Development Strategies 2010–2020. At:http://kenyagreece.com/Agricultural%20Sector%20Development%20Strategy

Government of Kenya (GOK). (2010b). National Climate Change Response Strategy (NCCRS). Government Printer. Nairobi.

Government of Kenya (GOK). (2012). Vision 2030 Strategy for Northern Kenya and other Arid lands. Nairobi

Government of Kenya (GOK). (2013). National Climate Change Action Plan 2013-2017, vision 2030

Gubta, J., Termeer &Klostermann, J. (2010). The Adaptation Capacity Wheel. A method to assess the Inherent Characteristics of Institutions to enable the Adaptive Capacity of the Society, Environmental science and policy.

Gunderson.L.H & Holling, C.S (2002). Understanding transformations in human and natural systems. United Nations development programs Island press, Washington D.C, USA.

Gbetibouo, G. (2009). Understanding Farmers' Perception and Adaptation to climate Change and variability, A case study of Limpopo Basin, South Africa. IFPRI Discussion paper 00849

Groves, R.M., Pericheva, E. (2008). The impacts of non. Response rate on non-response bias. A meta- analysis published by Oxford University. Oxford.

Growing Africans Agriculture (AGRA), (2017). Food Friday, improving potato production in Nyandarua County.

Hamilton, M. B., (2009). Online survey response rates and times. Background and guidance for an industry super survey.

Hancock, R., Morris, W., Ducreux, L., Morris, J., & Verral, S. (2013). Physiological biochemical and molecular responses of the potato (Solanum Tuberosum.L) Plant to moderately elevated temperature. New York.

Hansen, J., Ruedy, R., Sato, M., & Lo, K. (2006). Bird Species and Climate Change. NASA Goddard Institute for Space Studies and Columbia University Earth Institute, NewYork, NY, 10025, USA. http://data.giss.nasa.gov/gistemp/2005/

Hijmans, J. R., (2003). The effect of climate change on Global potato production, International Potatoes center (CIP) Peru.

Hope, M., Yamamoto S., Malika, A., & Sauerborn, R. (2012), Household's perception of climate change and Human Health Risk: A community perception. Environmental Health 11, at http://www.ehjournal.net/content/11/111.

Hollings, C.S., (1973) Resilience and stability of ecological system. Annual review of ecology and systematic 4: 1-24

Hulme, M., Doherty, R., Ngara, T., New, M., & Lister, D. (2001). African climate change: 1900– 2100. Climate Research 17: 145-168.

Ickowicz, A., Ancey, V., Corniaux, C., Duteurtre, G., Poccard, R., Touré, I., Vall, E., & Wane, A. (2012). Crop–livestock production systems in the Sahel – increasing resilience for adaptation to climate change and preserving food security.

Ifejike, S.C., (2010). Resilient adaptation to climate change in African Agriculture. Deutsches Institute. Germany

Info Resources, (2008). Potatoes and climate. Langgasse Zollikofen Switzerland.

Intergovernmental Panel on Climate Change, IPCC. (2001). Impact, Adaptation and vulnerability of climate change, contribution of working group 11 to the third Assessment Report of Intergovernmental Panel on Climate Change writing team J. Adejuwon, C. Azar, W. Baethgen, C. Hope, R. Moss, N. Leary, R. Richels, J.-P. van Ypersele. Cambrige University Press

Intergovernmental Panel on Climate Change, IPCC. (2007). Climate Change, A synthesis report. Contribution of working Group 1,11 and 111 to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change.Core - writing team Pachauri R.K, ResingerA (eds) IPCC Geniva Switzerland.

Intergovernmental Panel on Climate Change, IPCC. (2014). Impact, Adaptation and vulnerability of Climate Change, contribution of working group 11 to the Fourth Assessment report of the Intergovernmental Panel on Climate Change, writing team: Book M, Niang A, Nyong C, Vogel A, Githeko M, Medany B, Osman Elashu, R. Tabu &Yanda p. Cambrige University Press.

Intergovernmental Panel on Climate Change, IPCC. (2010). Food security and food production systems. In: Climate Change: Impacts, Adaptation, and Vulnerability. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, writing team Field, C., Barros, V., Dokken, K., Mach, M., Mastrandrea, T., Bilir, M., Chatterjee, K., Ebi, Y., Estrada, R., Genova, B., Girma, E., Kissel, A., Levy, S. MacCracken, P., Mastrandrea, & White, L. Cambridge University Press, Cambridge, United Kingdom andNew York, NY, USA, pp. 485-533.

Intergovernmental Panel on Climate Change, IPCC. (2012). Managing the Risks of Extreme Events and Disasters to Advance ClimateChange Adaptation. A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change [Field, C.B., V. Barros, T.F. Stocker, D. Qin, D.J. Dokken, K.L. Ebi, M.D. Mastrandrea, K.J. Mach, G.-K. Plattner, S.K. Allen, M. Tignor, and P.M. Midgley (eds.)], Cambridge University Press, Cambridge, UK, andNew York, NY, USA, 582 pp.

Intergovernmental Panel on Climate Change, IPCC. (2013). Climate Change 2013: The Physical Science Basis. Contribution of Working Group I to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change [Stocker, T.F., D. Qin, G.-K. Plattner, M. Tignor, S.K. Allen, J. Boschung, A. Nauels, Y. Xia, V. Bex and P.M. Midgley(eds.)]. Cambridge University Press, Cambridge, United Kingdom and New York, NY, USA, 1535 ppJ. Climate, 5, 525-531.

Israel, G.D. (1992) Determining Sample Size. University of Florida Cooperative Extension Service, Institute of Food and Agriculture Sciences, EDIS, Florida.

Janssen, S., Wiersema, S., Goos, H., Wiersema, W. (2013). The value chain for seed and ware Potatoes in Kenya; Opportunity for Development

Jokastah, K., Walter, F., & Davis., H. (2013). Smallholder Farmers'perception of the Impacts of climate change and Variability on Rain-fed Agricultural Practices in Semi-Arid and Sub-humud region of Kenya.

Jovovic, Z., Micev, B., & Velimirovic, A. (2016). Impact of climate change on potato production in Montenegro and options to mitigate the adverse effects. Acad. J. Environ. Sci. 4(3): 047-054.

Juana, S., Zibanani, K., & Okurut, F. (2013). Farmers' Perception and Adaptation to Climate Change in Sub-Sahara Africa. A synthesis of Empirical Studies and implications for public Policy in African Agriculture. At http://dx.doi.org

Juana, J. Mangadi, K., & Strzepek K. (2012). The Socioeconomic Impacts of Climate Change on Water Resources in South Africa.Water International 37(3) 265-278.At http://dx.doi.org/10.1080/025080602012.687505.

Juma, O. (2015). Assessing the Potential Effects of Climate Variability and Change on livestock in Arid Lands Kenya

Juma, S. (2015). Impact of Climate Variability and Change on Rain-fed Farming System in selected Semi-Arid Area of Tanzania

Kabubo, M. & Karanja, F. (2007). The Economic Impact of Climate Change on Kenya Crop Agriculture. A Ricardian Approach, Global and Planetary Change.

Kaguongo, W., Gildemacher, p., Demo, p., Wagoire, w., Forbes, G., Fugile, K& Kinyae p. (2008). Farmers practices and adoption of improved potato variety in Kenya and Uganda, Social Science Working paper, Lima. Peru.

Kabanda T. (2011). Impacts of Climate Change on Agriculture: Collapsing of Dry Land Potato Farming in North East South Africa, North West University, South Africa.

Karanja, A. (2013). Analysis of rainfall variability on Irish Potato production in Ol-joro-orok Division Nyandarua County. Kenya

Karanja, A., Ondimu, K., & Recha, c. (2017). Analysis of Temporal Drought Characteristics using SPI drought Index based on rainfall data in Likipia West sub-county. Department of Geography, Egerton University. Kenya.

Kareri, R. (2015). Geography of Kenya. Indiana University. India

Kenya Agricultural Research Institute. (2005). Status of the Potato Industry in Kenya. Potato Development and Transfer of Technology Report. KARI. Nairobi: Kenya Agricultural Research Institute.

Kenya National Bureau of Statistics (KNBS) & Society for International Development (SID)(2013). Exploring Kenya's Inequality- pulling apart or pooling together. Kenya

Kenya National Bureau of Statistic (KNBS, 2015). County Statistic Abstract. Nyandarua Caounty.

Kenya national Bureau of Statistic (KNBS, 2019). Population by County and Sub-county volume 1. Counting our people for sustainable Development and Devolution of services. Kenya.

Kenya National Federation of Agricultural Producers (KENFAP), (2013). A guide to potato production and post harvest management in Kenya.

Kenya Ministry of Agriculture, Livestock and Fisheries, MoALF. (2016). Climate Risk Profile for Nyandarua, County climate Risk Profile Series. Nairobi, Kenya.

Kenya National climate Action Plan, KNCAP. (2014). Climate Change and the Agricultural Sector. Published Climate change Business Briefing Note atwww.iisd.org

Kenya News Agency, (2019). Potato production to rise in Nyandarua.

Kenya Horticulture Competitiveness Project (KHCP), (2013). A guide to potato production in Kenya.

Kerlinger, F.N., (1978). Foundation of Behavioural Research (2rd edition New York.

Kiarie, S. (2016). Effects of Treads of Climate Variability and Small-Scale Farmers Perception and Adaption Strategies in Kijabe Location, Kiambu County. Kenya.

Kidanu, A., Kibret, K., Hajji, J., Mohammed, M., & Ameha, Y. (2016). Farmers perception towards climate change and their adaptation measures in Dire Dawa Administration Eastern Ethiopia. Ethiopian Institute of Agricultural Research. Ethiopia

Kinoti, J., Zhongbo, S., Woldai & Kiteme, B. (2010). Integrating socioeconomic aspects in spatial multi-criteria evaluation process for selecting Rainwater harvesting sites as a mitigation measure to climate change in Sub Sahara Africa. Centre for Training and integrated Research in ASAL Development (CETRAD) Nanyuki, Kenya.

Kinyae, P.M., Lungaho, c., Njenga D.N., & Kabira J.N. (1996). Adoption of potato Production Technology in Nyandarua District, Kenya. Proceedings of the first KARI Socio-economic conference, Kenya Agricultural Research Institute. Nairobi

Kinh'uyu, S.M., Ogallo, L.A., & Anyamba, E.K., (2000). Recent trends of minimum and maximum surface temperatures over Eastern Africa. Journal of climate change 13, 1-11

Kombo, D.K., & Deino, L.A. (2006). Proposal and Thesis writing: an introduction. Paulines publication Africa. Nairobi.

Kotikot, S. & Onywere, S. (2015). Application of G.I.S and remote Sensing Techniques in Frost Risk Mapping for mitigating Agricultural Losses in Aberdare Ecosystem. Kenya. Gecarto international.

Lee, J., Nadolnyak, D., & Hartarska, V (2012). Impact of Climate Change on Agricultural Production in Asian Countries: Evidence from Panel Study.Department of Agricultural Economics and Rural Sociology, 202 Comer Hall, Auburn University, Auburn, AL 36849-5406

Legesse, B., Ayere, Y., &Bewket, W. (2013), Small-Holders Farmers' perception and Adaptation toclimate Change and Variability in Doba District. Ethiopia at http://asian.j.empir-res.org

Leiserowitz, A. (2006) Climate Change Risk perception and policy preferences: the role of affect, imagery and values, Climate Change, 77,45-72

Linus, F., Martin, S. &, Antony, H. (2014). Series, Potato Production in Changing Climate.111 Whate is in Storefor the Eastern Free State?

Lobell D. & Burke M. (2008). Why are agricultural impacts of climate change so uncertain? The importance of temperature relative to precipitation. Environ. Res. Lett. 3, 1–8

Madisson, D. (2006). The Perception and Adaptation to Climate Change in Africa.CEEPA. Discussion paper no.10 Center of Environmental Economy and Policy in Africa.University of Pretoria South Africa

Mall, K., Ranjeet, S., Akhilesh, G., Srinivasan, G., & Rathore, L. (2006). Impact of Climate Change on Indian Agriculture: A Review at http://dx.doi.org/10.1007/s10584-006-9236-x

Manyuli, T., Cihire, K., Rubabura, D., & Mutima, K. (2017). Farmer's perception, believes, knowledge and management practices of potatoes Pest in South-Kivu province, Eastern of Democratic Republic of Congo.

Marshall, N. A., and A. Smajgl. 2013. Understanding variability in adaptive capacity on rangelands. *Rangeland Ecology and Management* 66(1):88-94. http://dx.doi.org/10.2111/REM-D-11-00176.1

Mendelsohn, R., & Dinar, A. (1999). "Climate change, agriculture, and developing countries: does adaptation matter?", TheWorld Bank Research Observer 14: 277–293

Mendelsohn, Robert; Dinar, Ariel; Basist, Alan; Kurukulasuriya, Pradeep; Ihsan Ajwad, Mohamed; Kogan, Felix; Williams., & Claude. (2004). Cross-sectional analyses of climate change impact. Policy, Research working paper series; no. WPS 3350. Washington, DC: World Bank. http://documents.worldbank.org/curated/en/603561468780598421/Cross-sectional-analyses-of-climate-change-impacts

Micev, B. (2014). Climate change and flooding; first national platform for Disaster Risk reduction, podgorical.

Ministry of Agriculture (MoA). (2004). National Policy on potato industry. Nairobi Government Printer

Ministry of Agriculture (MoA) (2006). Strategic Plan 2006-2010. Nairobi: Ministry of Agriculture

Ministry of Agriculture (MoA). (2007). Economic review of Agriculture. The central planning andmonitoring unit Nairobi. Nairobi.

Ministry of Agriculture, (MoA). (2012). Annual report

Ministry of Agriculture (MoA). (2017). Nyandarua County Potato Production strategic plans 2017-2021

Ministry of Agriculture, Livestock and Fisheries (MoALF). (2016). The National potato Strategy 2016-2020.

Modisane, C.P., (2007). Yield and quality of potatoes as Affected by calcium Nutrition, temperature and Humidity. Faculty of Natural and Agricultural science. University of Pretoria

Monica, W.N., (2013). Enhancing Climate Change Adaptation Through utilization of social & environmental opportunity for Agro-pastoral Community in Kieni, Nyeri county

Moshrik, R., Muhmoud, A., Mohammed, J. (2011) Statistical Examination of frost characterization: A case of Global Warming Impact in Jordan Journal of water Resources and protection 3. 620-627

Mugenda, O., & Mugenda, A. (1999). Research Methods: Qualitative and Quantitative Approaches. Nairobi: Acts Press.

Mugenda, O., & Mugenda, A. (2003). Research Methods: Quantitative and qualitativeapproaches. Nairobi: Acts Press.

Muller, J. (2017). Cultivating climate change resilience in agri-food systems: Responses to natural disasters and emerging climate risks in Queensland's fresh produce supply chains, Australia.

Mutembei, M. Gachene, C., Chemining' wa, G. & Kaluma, A. (2017), Farmers' perception, Exposure and Response to Climate Variability in Mwea. Kenya.

Muthoni, J., Hussen, s., & Rob, M. (2013). Potato production in Kenya; farming systems and production constrains. Journal of agricultural science. Canadian Center of science Education.

Muthoni, J. & Kabira J.N., (2015). Potato production in Hot Tropic areas of Africa: progress made in breeding for heat Tolerance. National potato Research Center, Tigoni Kenya.

Muthoni, J., Mbiyu, M. (2017). Climate change, its likely impacts on potato (Solanum tuberrosum l.) production in Kenya and plausible coping measures.

Muller, C., Cramer, W., Hare, W.L. & Lotze-Campen, H. (2011) Climate Change Risks for African Agriculture. Pro- ceedings of the National Academy of Sciences of the United States of America, 108, 4313-4315. http://dx.doi.org/10.1073/pnas.1015078108

Munyuli, T., Cihire, K., Rubabura, D., Mitima, K., Yajuamungu, K., Nabintu, T., Emmanuel, K., Ombeni, B., Manderena, U., Eloi, C., Théodore, T., Meschac I, & Remy, M. (2017) Farmers' perceptions, believes, knowledge and management practices of potato pests in South-Kivu Province, eastern of Democratic Republic of Congo.

Mbaisi, C.N. (2014). Impacts of climate change on Agricultural production in Kenya. Mitigation and adaptation strategies in Maize Production in Nzoia River Basin. Kenya

Mbugua, G.K., (2016). A thesis on effect of climate variability on out-put and Yield of selected crops in Kenya. Kenyatta University

Mjuma, A. N. (2014). Regional Training course on sampling for Agricultural and Rural core data. Items for Agricultural and rural statistics. Statistical institute for Asia &the Pacific (SIAP)

Mmaduakonam, A. (1998). Behavioural learning theory. AWka Eradition Publishers

Mwaniki, F. (2016). Kenyan Farmers' perceptions and adaptation to climate change before and after a radio programme intervention. PHD Thesis, James Cook University.

Mwangi, G.K. (2017) Adapting to climate change in Kenya. A case study of Ndeiya Division Kiambu County. Kenya.

Monica, W.N., (2018). Enhancing Climate change adaptation, through utilization of social and environmental opportunities For Agro-pastoral community of Kieni Nyeri County.

Nagarajan, S., & Minhas, S. (1995). Inte modal elongation: Apotential Screening Techniques for heat tolerance in potato. Potato research Institute. India.

Naintoh, B. M., Wantim, N.M., Ndonwi, S.A. (2018). Assessing the effects of climate change and variability on Irish potato production from 1995 to 2015 in Tubah sub-Division, North- west region Cameroon.

Nangoli, S. (2019). A thesis on effects of servant leadership Behavour Attitudinal Loyalty and perceived fairness on employee commitment in Public hospitals in Uganda submitted to Moi University. Kenya

National Environment Management Authority, NEMA (2010). Chapter 3: Climate Change and Variability. Kenya State of the Environment and Outlook 2010

Nelson, D., Adger, W., & Katrina, B. (2007). Adaptation to environmental Changes: Contribution of a Resilience Framework, Annual Review of Environment and Resources, vol 32; 395-419 https://www.annualreviews.org/doi/10.1146/annurev.energy.32.051807.090348

Niang, I., Ruppel, O.C., Abdrabo, M.A., Essel, A., Lennard, C., Padgham, J. and Urquhart, P. (2014) Africa. In: Barros, V.R., Field, C.B., Dokken, D.J., Mastrandrea, M.D., Mach, K.J., Bilir, T.E., Chatterjee, M., Ebi, K.L., Estrada, Y.O., Genova, R.C., Girma, B., Kissel, E.S., Levy, A.N., MacCracken, S., Mastrandrea, P.R. and White, L.L., Eds., Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part B: Regional Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change, Cambridge University Press, Cambridge, 1199-126

Nonhebel, S. (1993). A PHD Thesis on the importance of weather data in crop growth simulation models and assessment of climate change effects. Wagenigen, agricultural University. Netherlands

North East Climate Adaptation Science Centre, NECASC. (2016). Ecological and Vulnerability and species response to Climate Change. At http://nescs.umass.edu/content/

Nganga, K (2006). Climate change Impact, Vulnerability and Adaptation Assessment in East Africa. UNFCC African Regional Workshop on Adaptation Accra, Ghana.

Nderitu, J., Kabira, J., Kipkoech, D. & Ngaru, P. (2014), Report on NCST seed potato projects 2013-2014, proceedings of the seed potato project workshop.

Ngigi, S. N. (2003). What is the limit of up-scaling rainwater harvesting in a river basin? *Phys. Chem. Earth, Parts A/B/C* **28**: 943– 956

Ngigi, S.N, (2009). Climate change adaptation strategies: Water Resources Management Options for Smallholder Farming Systems in Sub-Saharan Africa.The MDG Centre, East and Southern Africa. The Earth Institute at Columbia University. New York.

Nhemachena, C., & Hassan, R. (2007). Micro-level Analysis of Farmers' Adaptations to Climate Change in Southern Africa. IFPRI, Environment and Production Technology Division. Washington, DC: International Food Policy Research Institute.

Njenga, N.M., Muna, M.W. & Muriuki, J.N., (2013). Perceived impacts of climate Variability and change on small-scale farmers in North Kinangop location. Kenya. International journal of climate change impacts and Response.

Nkwusi, G., Adeaga, S., Ayejugo, S., Anruk, A (2015). Climate Change: Farmers Awareness, perceptions & Responses in Lagos State.

Nyakundi, J.O., & Njoka, T.J (1991). Impact of Climate Change on Agriculture and forest in Africa: A paper in a change in weather, African Perspective on climate change.

Nyandarua County Government (2013), Nyandarua County Integrated Plan 2013-2017.

Nyandarua County Government (2017), Nyandarua County Potato Strategies.

Nyandarua County Government (2013), Exploring Kenya's Inequality, pooling apart or pooling together.

Nyagaka, D. (2009). Analysis of production efficient in Irish Potato production. The case study of Nyandarua North District.

Nyongesa, M., Saumtally, S.& Bindi, M. (2008). Climate change – can potato stand the heat. Kenya agricultural Research Institute (KARI), Mauritius Sugar industry Research institute. Mauritius Agricultural Meteorologist. University of Florence, Italy.

Obidiegwo, J.E., Glenn, J.B., Hamlyn, G.J & Ankush, p. (2015). Coping with drought stress and adaptive responses in potato and perspectives for improvement. James, Halton Institute, Dundee, UK.

Ochenje, I., Ritho, C., Guthiga P., & Mbatia O. (2016). Assessment of Framers' perception to the effect of Climate Change on Water Resources at Farm Level, A case study ofKakamega County. Kenya

Okaka, F. O., (2016). Urban Residents Perceptions and Adaptive Capacity and behavior to the Health Risks of Climate Change in Mombasa City. Kenya

Okoth-Ogendo, H.W.& Ojwang, J.B., (1995) A Climate for Development: climate change policy options for Africa. African Centre for Technological Studies, Nairobi, Kenya, 264 pp

Omondi, S., Kidali, J., Ogali, I., Mugambi, J, & Letoire J (2014). The status of Livestock Technologies and Services in the Southern Maasai Rangelands of Kenya. African Journal of Agricultural Research 9(15) 1166-1171

Omolo, N., Ngesa, O., & Mafongoya, P. (2017) Gender and Resilience to Climate Variability in Pastoralists Livelihoods System: Two Case Studies in Kenya.

Olanya, O., El-Bedewy, R., Adipala, E., Hakiza, J., Namanda, S., & Luhango, C. (2002). Estimation of yield loss caused by late bright and effects of environmental factors on late bright severity in Kenya and Uganda. African crop science proceedings.

Olanya, O., Lunjaho, C., Nderitu, S., Kabura, J., & Waling, A. (2006). Yield performance and release of four late Bright Tolerance potato Variety in Kenya.

Olena, S. (2016) "Cultural Resilience Theory as an instrument of modeling Human response to Global Climate Change. A case study in the North- Western Black Sea region on the Pleistocene-Holocene boundary", RIPARIA 2 (2016), 1-20. At http://hdl.handle.net/10498/18445

Orodho, J. (2002). *Techniques of Writing Research Proposals and Reports in Education and Social Sciences.* Nairobi: Masola Publishers.

Orina, D. (2009). Analysis of production efficiency in Irish Potato production in Kenya. A thesis submitted to the Graduate school of Egerton University.

Otiende B. (2009). The Economic Impacts of Climate Change in Kenya, Riparian Flood Impactsand Cost of Adaptation. Accessed at http://static.weadapt.org/knowledge-base/files/

Patt, A., Suarez, P., & Gwata, C. (2005). Effects of seasonal climate forecasts and Participatory workshops among subsistence farmers in Zimbabwe. Proceedings of theNational Academy of Sciences of the United States of America. 102: 12623-12628.

Piymuza, K., Radzka, E., & Lenartowicz, T. (2015). The effects of weather Conditions on Early Potatoes trends in East Central Poland.

Rai, S. S. (2019). Methods to handle missing data. Oracle Data science. Com at https://www.datascience.com

Ramasamy, S. (2012). Managing climate risks and adapting to climate change in the agriculture sector in Nepal. Food & Agriculture Organization of the United Nations. Rome, Italy.

Rebetez, M. (1996). Public expectations as an element of human perception of climate change. *Climate Chang* 32:495–509.

Richard, J & Klein T. (2004). Approaches, Methods and Tools for Climate Change Impact, Vulnerability and Adaptation Assessment, Keynote lecture to the In-Session Workshop on Impacts of, and Vulnerability and Adaptation to, Climate Change, Twenty-First Session of the UNFCCC Subsidiary Body for Scientific and Technical Advice, Buenos Aires, Argentina.

Reich, P.F., Numben, S.T., Almaraz, R. and Eswaran, H. (2001) Land Resources Stress and Desertification in Africa. Agro-Science, 2, 1-10

ROK, (2018). Kenya Climate Smart Agriculture, Implementation framework. 2018-2027, Kenya

ROK (2000-2012). Nakuru District annual Report.

Sehu, N., Mishra, D. (2013). Analysis of perception and adaptability Strategies of the farmers to Climate Change in Odisha. India APCBEE Procedial 5, 123-127.

Singleton, R., & Strants, B. (2005). *Approaches to Social Research*, 4th ed., Oxford, Oxford University Press.

Serigne, T., Verchot, L. &Mackensen, J. (2006). Climate Change and Variability in the Sahel Region: Impacts and Adaptation Strategies in the Agricultural Sector. ICRAF and UNEPI at https://www.researchgate.net/file.PostFileLoader.html?id=56e1790fb0366d182118beb1

Seo, S., Mendelsohn, R. (2008). A Structural Ricardian Analysis of Climate Change Impacts and Adaptations in African Agriculture. Policy Research Working Paper No. 4603. World Bank, Washington, DC. © World Bank. https://openknowledge.worldbank.org/handle/10986/6770

Sophie, S. (2018). Potato variety adoption and dis-adoption in Kenya, International Potato Center (CIP). Kenya

Scheaffer, R.L., Mendenhall, W., & Ott, L. (2006). *Elementary survey sampling.* Belmont Duxbury press.

Shahid, S. (2012). Vulnerability of power sector of Bangladesh to Climate Change and extreme weather events. *Regional environmental change*, 12(3) 595-606.

Skambraks, A., (2014). Small Holders farmers' adaptation to climate change in Zenzelima Ethiopia. A case study of female and male farmers' perception of and ability to Adapt to climate change in Zenzelima. Ethiopia

Slegers, M. (2008). "If only it would rain" Farmers Perceptions of rainfall and Drought in Semi-arid Central Tanzania, journal of Arid Environment. 72, 2106-2123 at http://dx.doi.org

Smithers, J., B & Smit (1997) 'Human Adaptation to Climatic Variability and Change' *Global Environmental Change*, 7 (2) 129-146.

Stefanovic, J., (2015). Small Holders farming systems in Kenya. Climate change perception, adaptation and Determinants.

Tierney, J., Abram, N., Anchukaitis. K., Evans, M., Giry, C., Kilbourne, H., Saenger, C., Zinke, J. (2015). Tropical sea surface temperatures for the past four centuries reconstructed from Coral archives. *Paleoceanology.* 30-226-252.

Tubey, J. (2009). University Tourism Training &career success in the Tourism industry in Kenya. Case study of Moi University tourism training programmes.

The Organic Farmer (TOF), (2015). Independent magazine for East African Farming, Icepe- African Insect Science for food and Health Nairobi. Kenya.

The star Kenya, (2019). Is this the end of chips? Potatoes at risk of climate change on Feb. 05, 2019, at https://www.the-star.co.ke/news/2019/02/05/is-this-the-end-of-chips-potatoes-at-risk-of-climate-change_c1889956.

Uddin, M., Wolfgang, Bokelmann & Dunn, E. (2017), Determinants of farmers perception of climate change, A case study of the coastal Region of Bangladesh. Found at http://www.scrip.org/journal/ajcc

United Nations Environment Programme, UNEP. (2009). Kenya: Atlas of Our Changing Environment. Division of Early Warning and Assessment, (DEWA). United Nations Environment Programme (UNEP), Government of Kenya (GoK), Regional Centre for Mapping of Resources for Development (RCMRD) and United States Geological Survey (USGS).

United Nations Development Plan, UNDP. (2007). Human Development Report. 2007/2008/: Fighting Climate Change: Human solidality in divided world: New York, United Nations development program. Washington, DC, USA.

United Nations Development Plan, UNDP. (2012). Climate Risks, Vulnerability and Governance in Kenya: A review. Climate Risk Management Report November 2012.

United Nations Framework Convention on Climate Change, UNFCCC. (2012). Summary of the Climate Change Conference in Doha, December 2012.at http://enb.iisd.org/vol12/enb12567e.html.co.

Välikangas, L., & Hamel, G. (2003). The Quest for Resilience' Harvard Business Review. September 2003

Walter S., (2006). Social ecological system ‘the ability of a system to respond and absorb disturbances and still retain its basic function & structure. Research Gate, P:1.4050

Watson, G., Terrazas, F., Suarez, V., Thiele, G., Walker, T. and Devaux, A. (2004). Analyzing potato productivity in farmers’ fields in Bolivia. Bolivia.

World Resources Institute Climate Analysis Indicators Tool, WRICAIT. (2017). Global Warming Potentials (GWPs) are from the Intergovernmental Panel on Climate Change (IPCC) Second Assessment Report (SAR) WRICAIT draws on data from the International Energy Agency (IEA), primarily, for energy emissions, the US Environmental Protection Agency for IP and waste emissions, and the Food and Agriculture Organization (FAO) for LUCF and agriculture emission.

World Trade Organisation (WTO) & United Nations Environmental Programme UNEP. (2009). Trade and Climate Change. WTO Publication Geneva.

World Resources Institute WRI (2007). Kenya Ministry of Environment and NaturalResources, Kenya Ministry of Planning and National Development, & International Livestock Research Institute. (2007). Nature’s benefits in Kenya: An atlas of ecosystems and human well- being. Washington, DC and Nairobi: World Resources Institute. Page34.

Wolf, S., & Rudich, A. (1990). Effects of temperatures and photo period on assimilate Partitioning in potato plants canals of Botany.

World Water Assessment Programme WWAP. (2006) Kenya national water development report (Report No. UN-WATER/WWAP/2006/12). Report prepared for the 2nd UN World Water Development Report Water: A Shared Responsibility

Yesuf, M., Falco, D., Deressa, S., Ringler, T., & Kohlin, G.(2008). The Impact of Climate Change and Adaptation on Food Production in Low-Income Countries: Evidence from the Nile Basin, Ethiopia, EDRI.

Yirga, C.T., (2007). The dynamics of soil degradation and incentives for optimal management in central high lands of Ethiopia. University of Pretoria, South Africa.

APPENDICES

Appendix I: Participants in the Survey and FGDs

Dear

My name is Baetrice Wangui Ndegwa, I am a student from Moi University undertaking a PhD in Geography. I am carrying out a research study on effects of climate change and variability on Irish Potato production. You are being asked to take part in this research study. This information is provided to tell you about the study. Please read this form carefully. You will be given a chance to ask questions. If you decide to be in the study you will be given a copy of this consent form for your records. Taking part in this research is voluntary. You may choose not to take part in the study. If after data collection you choose to quit, you can request that the information provided by you be destroyed under supervision- and thus not used in the research study.

The purpose of this study is to find out Ndaragwa Agro-ecological zone residents' perception of climate change and variability effects on Irish potato production and their adaptive capacity to the risks. The research will involve you responding to interview questions from a questionnaire and a focus group discussion later on with few selected participants. You have been selected to participate in this study because it is believed that you can adequately provide information around the study topic due to your residency in the Ndaragwa area. You will be in this study for the duration of the interview that will approximately last between 30 to 45 minutes and may participate in a focus group discussion if selected and the discussion may last about 90 minutes. We are asking you to help us learn more about your view about climate change and variability and whether you think it poses risks on production of Irish Potatoes. The study will require that you respond on matters that will be presented to you as sincere as it is possible. Information provided will be kept confidential and used solely for purposes of academic. Taking part in this research study is voluntary

If you have any questions about your participation in this study you may contact Beatrice Wangui Ndegwa, Deprtament of Geography, Moi University, P.O. Box 3900 Eldoret, Mobile 0724122723

Consent of Subject

I have read or have had read to me the description of the research. The investigator or her representative has explained the study to me and has answered all of the questions I have at this time. I have been told of the potential risks, discomfort and side effects as well as possible benefits (if any) of the study. I freely volunteer to take part in this study.

Name of Participant…………………………………..……………………….

Signature/thumb print……………………………….Date & Time…………………….

Name of Person obtaining consent……………Signature………………..Date………..

Name of Investigator……………………Signature……………………Date………….

Appendix II: Questionnaire

PART I: RESPONDENT'S PERSONAL DETAILS

1. Gender: Male (   ) Female [   ]

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

3. Highest level of Education: Primary [   ] Secondary [   ]   College diploma [   ] University undergraduate [   ] Master's degree [ ] PhD [   ]

Others (Specify)…………………………………………………….............................

4. For how long have you been practicing potato farming?

Less than 2 years ( ), between 2-5years ( ), between 5-10years ( ), over 10years ( )

5. What is the size of land where you have practicing potato farming?

Less than 1 acres ( ) between 2-5 acres ( ), between 5-10 acres ( ), over 10 acres ( )

PART II: FARMERS' PERCEPTION ON CLIMATE CHANGE AND VARIABILITY

6. Do you understand what is meant by climate change and variability? Yes[ ] No **[ ]**

If yes, briefly describe what you understand by climate change ………………………

7. How do you access information on climate Variability?   (Multiple answers are accepted) 1=Media[ ]; 2= Internet[ ]; 3= Public library[ ]; 4=agricultural officers[ ]; 5=training[   ]; 6=farmers associations[   ]; 7=Private sectors[   ] 8= others (specify) …………………...

8. What aspect of your operations would you like to receive climate information for? (Multiple answers are accepted). 1= on- set of rains [ ]; 2=cessation of rains [ ]; 3=flood forecast[ ]; 4=drought forecast[ ]; 5=frost occurrence[ ]; 6=choice of seeds[ ]; 6= pest and or disease outbreaks[ ]; 7= others ……………………………………………………….

9. For the last 10-30 years (1985-2018) have you experienced any of the following, (ticking Multiple answers are accepted).

1=Heavy rains and hails[ ]; 2= Problems with frost[ ]; 3=drought[ ]; 4=crop diseases outbreak[ ]; 5=invasive (alien) plant species[ ]; 6=landslide[ ]; 7= food shortage[ ]; 8=water scarcity[ ].

10. From your own experience, how have rainfall and temperature changed between 1988 and 2018?

Rainfall: Increased [ ] Decreased [ ] No change [ ]

Temperature: Increased [ ] Decreased [ ] No change [ ]

11. For the last 10-30 years (1985-2018) which years did you experience severe;

Heavy rains………………………………………………………………………………

Drought…………………………………………………………………………………

Frost bite…………………………………………………………………………………

12. To what extent would you agree or disagree that the options indicated in the table below apply as possible reasons to responses by your household to the climate trend (Changes of temperature and rainfall)? (Mark the appropriate box)

SN	OPTIONS	Strongly disagree	Disagree	Neutral	Agree	Strongly agree
1	**Change in temperature**					
2	Increase in temperature					
3	Decrease in temperature					
4	No change in temperature					
5	Rainy season temperature decreases					
6	Dry season temperature increases					
7	Number of hot days increase					
8	Number of cold days increase					
9	**Change in precipitation**					
10	increase rainfall					
11	Extreme high rainfall					
12	Decrease rainfall					
13	Extreme low rainfall					
14	Late onset/ start of rainfall					
15	No change in rainfall					
16	Early onset/ cessation of rainfall					
17	Main rainy season rain decreases					

13. Have you experience any climate change and variability risks in your area?

Yes [ ]   No [ ]

If yes, would you please show the intensity of the problem?

		Intensity		
No	Problem/ risk	low	medium	High
A	Drought			
B	Frost			
C	Floods			
D	Pests $ diseases			
E	Crop failure			
F	Erratic rainfall			
G	Water shortage			
H	Food crisis			
I	Human health problem			

14. What makes you feel the way you have explained above?

....

15. How have climate information helped people to prepare for the effects of climate variability?

…………………………………………………………………………………………

…………………………………………………………………………………………..

PART IV: IMPACT OF CLIMATE CHANGE AND VARIABILITY ON POTATO PRODUCTION

16. What factors have influenced your decision to plant potato? (Kindly tick your answer Multiple answers are accepted). 1= water availability [ ]; 2= cultural values [ ]; 3= land tenure [ ]; 4= ability to resist to climate variability [ ]; 5= market availability [ ]; 6 = soil conditions [ ]; 7 = others (specify) ………………………………

17. What is your total yield production in potato per year in Kgs? …………………….

18. Potato yield has been increasing in the past ten years in this region. Yes ( ) No ( )

19. To what extend would you agree or disagree that the following risks in the table below affect potato production. (Mark the appropriate box)

SN	Options	Strongly agree	Agree	Neutral	Strongly disagree	Disagree
1	Drought					
2	Floods					
3	Frost bite					
4	Erratic rainfall					
5	High temperature					
6	Heat wave					
7	Wind pattern					
8	Humidity					

19b. In your opinion, explain how temperature and rainfall variation have affected potato production in your farm

……………………………………………………………………………………………

……………………………………………………………………………………………

……………………………………………………………………………………………

20. What are the reasons for high potato production?

………………………………………………………………………………………

20b What are the reasons for low potato production?

………………………………………………………………………………………

………………………………………………………………………………………

21a. Apart from climate related aspect, have you notice any other factor that affect potato production?

Yes [ ] No [ ]

21b.What are the factor (multiple answers are allowed); 1, soil degeration [ ] 2, pest and diseases [ ] 3, inadequate field officer [ ] 4, high cost of input [ ] 5, lack of clean seed [ ] Any others…………………………………………………………..………

PART V: ADAPTATION STRATEGIES

22. a) Which of the following strategies has your household undertaken in regard to potato farming especially in respond to changes in weather pattern? You can tick more than one answer.

- Grow potato varieties that mature faster [ ]
- Planting drought resistant crop [ ]
- Change planting dates (i.e. planting at first rain) [ ]
- Irrigating potato farms [ ]
- Focus more on non-farm activities [ ]
- Increase use of inorganic fertilizers [ ]
- Applying soil and water conservation mechanisms [ ]

- Mixing crops on the same land [ ]
- Migrating from dry to wet, river banks and wetlands [ ]
- Livestock keeping [ ]
- Rain water harvesting for irrigation [ ]
- abandon potato farming [ ]

Appendix III: Interview Guide

1. Are you aware of climate change and variability?
2. If yes how did you get the information about climate change and variability?
3. How has the rainfall and temperature trends in Ndaragwa changed over the last 30 years (1985-2018)?
4. Are there non-climate stressors that affect rain-fed potato farming practices in ndaragwa?
5. Are you aware of the effects of climate change to small scale potato farmers in Ndaragwa? Please can you explain these effects?
6. Are many people in this region still growing potatoes?
7. Has the production of potatoes been increasing or reducing for the past 10 years?
8. What is the major cause of either reduction of increase in potato production in this region?
9. Are there adaptation strategies being employed by small-scale potato farmers in Ndaragwa to counter the effects of climate variability? If yes which ones are they? If no why?
10. If the answer is yes above can you please explain the key challenges that hinder adaptation strategies among small-scale potato farmers in Ndaragwa?
11. Are there policies in place to mitigate the negative effects of climate variability to help the small-scale potato farmers to adapt to climate variability? If yes which ones are, they? If no why?
12. Are there any agricultural offices or governmental agencies that help small scale potato farmers in the area?
13. If yes what assistance do these offices offer to small-scale potato farmers to counter the effects of climate variability? Please explain
14. Who are affected most by the climate variability? (Low-income earners, Middle low-income earners, High income earners). Please explain

Appendix IV: Field Pictures

Plate 4.5: Training Sessions of the Research Assistants

Plate 4.6: Day 1 - Administering Questionnaire

Plate 4.7: A Research Assistant in the Field with A Farmer

Plate 4.8 &4.9: FDG Sessions with Participants

Appendix V: Research Letters

MOI UNIVERSITY
SCHOOL OF ARTS & SOCIAL SCIENCES

Telephone (053) 43001-8/43620
Telex No. MOI UNIVERSITY 35047
Fax No. (0321) 43047

P.O. BOX 3900
Eldoret
KENYA

DEPARTMENT OF GEOGRAPHY

19th February 2019

To
The Director
National Commission for Science, Technology and Innovation

RE: RESEARCH PERMIT FOR BEATRICE WANGUI NDEGWA: REG NO.SASS/D.PHIL/GEO/01/14.

This is certifying that Mrs. Beatrice Wangui Ndegwa is a PhD students in the department of Geography, Moi University. She successfully presented his research proposal entitled ***"Effects of climate change on rain fed Irish potato production in Ndaragwa Agro-ecological Zone Nyandarua"*** at a departmental seminar held on 17th January 2019. The department has therefore cleared her to proceed to the field for data collection. Kindly assist her process research permit to enable her undertake data collection.

Thanking you in advance.
Yours faithfully,

HEAD DEPARTMENT OF GEOGRAPHY
MOI UNIVERSITY
P. O. Box 3900
ELDORET-30100

William Kiplagat
HEAD, DEPARTMENT OF GEOGRAPHY

MINISTRY OF EDUCATION
State Department of Early Learning and Basic Education

Tel. No. 065-22288 **Nyahururu**

Fax: 065-32426 **Nyahururu**
Email:deonyandaruan@yahoo.com

Sub-county Education Office
Nyandarua North
P.O. Box 380
NYAHURURU

OUR REF: NYA/GEN/14/VOL.V/93 **25TH APRIL, 2019**

TO WHOM IT MAY CONCERN

This is to inform you that Beatrice Wangui Ndegwa is a research student from Moi University, who will be carrying out her research in Nyandarua North Sub-County for a period of four weeks. She will be carrying out research questionnaires and carrying out oral interviews in several areas assisted by 5 research assistants namely:-

1. Kamotho Gerald ID NO. 26089608
2. David Kinyanjui ID NO. 30048887
3. Hosea Mugo ID NO. 32620804
4. Faith Wangui ID NO. 31436261
5. Peter Wachira ID NO. 23766845

Any assistance accorded to him will be highly appreciated.

SUB-COUNTY DIRECTOR OF EDUCATION
NYANDARUA NORTH
P. O. Box 380 - 20300, NYAHURURU
Sign.....................................

ALFRED SAITAGA
SUB-COUNTY DIRECTOR OF EDUCATION
NYANDARUA NORTH.

NATIONAL COMMISSION FOR SCIENCE, TECHNOLOGY AND INNOVATION

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

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

Ref: No. **NACOSTI/P/19/93023/29662**

Date: **25th April 2019**

Beatrice Wangui Ndegwa
Moi University
P.O Box 3900-30100
ELDORET.

RE: RESEARCH AUTHORIZATION

Following your application for authority to carry out research on ***"Effects of climate change on rain fed Irish potato production in Ndaragwa agro-ecological zone Nyandarua County."*** I am pleased to inform you that you have been authorized to undertake research in **Nyandarua County** for the period ending **25th April, 2020.**

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

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

GODFREY P. KALERWA MSc., MBA, MKIM
FOR: DIRECTOR-GENERAL/CEO

Copy to:

The County Commissioner
Nyandarua County

The County Director of Education
Nyandarua County.

THE SCIENCE, TECHNOLOGY AND INNOVATION ACT, 2013

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

CONDITIONS

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

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

REPUBLIC OF KENYA

NACOSTI

National Commission for Science, Technology and Innovation

RESEARCH LICENSE

Serial No.A 24346

CONDITIONS: see back page

THIS IS TO CERTIFY THAT:
MS. BEATRICE WANGUI NDEGWA
of MOI UNIVERSITY, 0-3100 Eldoret,has been permitted to conduct research in
Nyandarua County

Permit No : NACOSTI/P/19/93023/29662
Date Of Issue : 25th April,2019
Fee Recieved :Ksh 2000

on the topic: ***EFFECTS OF CLIMATE CHANGE ON RAIN FED IRISH POTATO PRODUCTION IN NDARAGWA AGRO-ECOLOGICAL ZONE NYANDARUA COUNTY***

for the period ending:
25th April,2020

....
Applicant's Signature

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