ANALYSIS OF RAINFALL VARIABILITY ON IRISH POTATO PRODUCTION IN OL-JORO-OROK DIVISION, NYANDARUA COUNTY, KENYA.

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A thesis submitted in partial fulfilment for the award of the degree of Master of Arts in the School of Humanities and Social Sciences of Kenyatta University

NOVEMBER 2013
DECLARATION

This thesis is my original work and has not been presented for a degree in any other University or any other award.

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DEDICATION

I dedicate this thesis to my parents who educated me and taught me that even the largest task can be accomplished if it is done one step at a time.
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TABLE OF CONTENTS

DECLARATION............................................................................................................ii
DEDICATION..................................................................................................................iii
ACKNOWLEDGEMENTS....................................................................................................iv
TABLE OF CONTENTS....................................................................................................v
LIST OF TABLES............................................................................................................... v
LIST OF FIGURES...........................................................................................................x
LIST OF PLATES.............................................................................................................xi
OPERATIONAL DEFINITIONS OF TERMS AND CONCEPTS.............................................xii
LIST OF ABBREVIATIONS USED IN THE STUDY............................................................xiii
ABSTRACT.......................................................................................................................xiv

CHAPTER ONE.................................................................................................................1

INTRODUCTION..............................................................................................................1

1.1 Background to the study problem............................................................................1
1.2 Statement of the problem.......................................................................................6
1.3 Research questions................................................................................................6
1.4 Research Hypotheses............................................................................................7
1.5 Study Objectives....................................................................................................7
1.5.1 General objective.............................................................................................7
1.5.2 Specific objectives............................................................................................7
1.6 Justification and significance................................................................................7
1.7 Scope and limitation of the study.........................................................................8
CHAPTER TWO................................................................................................................10

LITERATURE REVIEW..................................................................................................10

2.0 Introduction.............................................................................................................10
2.1 Climate and Weather Variability.........................................................................10
2.2 Non-weather variables......................................................................................16
2.3 Rainfall trends and potato yields......................................................................18
2.4 Rainfall characteristics and potato yields.......................................................21
2.5 Challenges facing potato production...............................................................24
2.6 Conceptual Framework....................................................................................25

CHAPTER THREE......................................................................................................28

RESEARCH METHODOLOGY.......................................................................................28

3.0 Introduction........................................................................................................28
3.1 Study area..........................................................................................................28
3.2 Target population...........................................................................................31
3.3 Sampling procedure.........................................................................................31
3.4 Pilot Study..........................................................................................................32
3.5 Data collection procedures..............................................................................32
3.5.1 Field data collection....................................................................................32
3.5.2 Primary data...............................................................................................32
3.5.3 Field data collection plan..........................................................................33
3.5.4 Administration............................................................................................33
3.5.5 Response rate.............................................................................................33
3.5.6 Secondary data collection.........................................................................34
3.5.7 Verification and validation of data.............................................................34
4.8.1 Analysis of the Adaptation measures.................................................................54
4.8.2 SWOT Analysis....................................................................................................55
4.8.3 Analysis of Strengths vs. Weaknesses.................................................................57
4.8.4 Analysis of Opportunities vs. Threats.................................................................65

CHAPTER FIVE.................................................................................................................74

SUMMARY OF FINDINGS, CONCLUSIONS AND RECOMMENDATIONS....................74

5.1 Summary of findings..............................................................................................74
5.2 Conclusions............................................................................................................76
5.3 Recommendations.................................................................................................78
5.3.1 Recommendation for policy Action.................................................................78
5.3.2 Recommendation for further research............................................................79

REFERENCE....................................................................................................................80

APPENDIX A; Questionnaires used in this study.........................................................87

APPENDIX A2: Annual Rainfall data (1999 – 2009)..................................................90

APPENDIX A3: Annual Potato yield data (1999 – 2009)............................................91
LIST OF TABLES

Table 4.1 Seasonal and annual rainfall variability index..........................42
Table 4.2 Seasonal and annual potato production variability index............46
Table 4.3 Summary of rainfall characteristics during the long rain season.....51
Table 4.4 Summary of rainfall characteristics during the short rain season...52
Table 4.5 Annual rainfall trend and potato production...............................52
Table 4.6 Correlations................................................................................54
Table 4.7 Farmers Adaptation measures...................................................55
Table 4.8 SWOT matrix.............................................................................56
Table 4.9 Respondents Background information.......................................60
Table 4.10 Respondents Background information Cont............................61
Table 4.11 Type of land ownership.............................................................63
Table 4.12 The Duration the respondents have grown Irish potatoes in Oljoro- orok.................................................................64
Table 4.13 Scientific methods of farming employed by farmers.................68
LIST OF FIGURES

Figure 2.1 Conceptual Framework for analyzing potato yield........................................27
Figure 3.1 Map of the study Area (Oljoro-orok Division map).................................30
Figure 4.1 Annual Rainfall data trend for years 1999 – 2009......................................39
Figure 4.2 Trend of Rainfall (mm) data: 1999-2009 – Long rain season..................40
Figure 4.3 Trend of Rainfall (mm) data: 1999-2009 – short rain season...............41
Figure 4.4 Trend of annual Potato yields in tons for the years 1999-2009.............43
Figure 4.5 Trend of potato yields in tons between 1999 and 2009- Long rain
Season..................................................................................................................................44
Figure 4.6 Trend of potato yields in tons between 1999-2009- Short rain Season..45
Figure 4.7a Annual rainfall data trend for years 1999 – 2009...............................47
Figure 4.8a Trend of Rainfall (mm) 1999-2009: Long rain season..................48
Figure 4.10 Type of activities carried out by the land user.....................................62
Figure 4.11 Distribution of the land holding...............................................................65
Figure 4.12 The indigenous methods of farming employed in the farms according to
the respondents.................................................................................................................67
Figure 4.13 Key challenges facing Irish potato farmers.........................................71
LIST OF PLATES

Plate 4.1 Potato bags with sisal net extension woven onto each bag which weighs from 110-150 kg. ............................................................. 73
OPERATIONAL DEFINITIONS OF TERMS AND CONCEPTS

Adaptations – Transformation of the environment into opportunities to sustain agricultural production.

Growing season - Is the difference between the onset and cessation of the rains when potatoes are planted, mature and harvested.

Households- Is a composition of a person or group of persons residing together within the same compound and have the same cooking and investment arrangements.

Livelihood – This is the major activity that is a source of income to the local people.

Rainfall variability - The quality of being uneven and unpredictable in a growing season.

Stakeholders- All those people who are involved in the day-to-day agricultural activities.

Weather impacts – Refers to the effect of rainfall variability on potato production.

Weather variability- Is defined as inter-seasonal rainfall variation within a specified geographical location.
LIST OF ABBREVIATIONS USED IN THE STUDY

ADC- Agricultural Development Co-operation
AEO – Agricultural Extension Officers
AEZ- Agro-Ecological Zone
CIP- International Potato Centre
DAO- District Agricultural Office
FTC – Farmers Training Centre
IPCC – Intergovernmental Panel on Climate Change
KARI – Kenya Agricultural Research Institute
KMD- Kenya Meteorological Department
KNBS-Kenya National Bureau of Statistics
MoA – Ministry of Agriculture
MoP – Ministry of Planning
NMS- Nyahururu Meteorological Station
ABSTRACT

This study analysed the effect of rainfall variability on potato yields in Oljoro-orok Division, Nyandarua County. The objective was to investigate the relationship between rainfall variability and Irish potato production in Oljoro-orok division. Specific objectives were: to assess the seasonal and annual rainfall and potato production trends and variability between 1999 and 2009, to analyse seasonal and annual rainfall characteristics and correlate them with potato production, to evaluate farmers’ adaptation measures to rainfall variability in potato production. Primary data were obtained from randomly selected farmers through questionnaires. Secondary data on rainfall and potato production were collected from Nyahururu Meteorological Station and District Agriculture Office respectively for the period of eleven years. Purposive sampling was used to select 300 farmers in the division. Proportionate sampling was used to select the sample of farmers in each of the three locations. The data collected were analyzed using descriptive statistics namely frequencies, percentages and means with the aid of Statistical Package for Social Science (SPSS) version 17.0. The results were presented using line and bar graphs, tables and pie charts. The findings were that annual rainfall and potato yield shows an increasing trend between 1999 and 2009. Rainfall has shown a decreasing trend during the long rain season and an increasing trend during short rain season. Rainfall variability is significant in both seasonal and annual trends ranging from -25.2473 in 2009 to +48.9891 in 2007 on the annual trend, -61.0170 in 2008 to +105.7627 in 2007 during the long rain season and -69.7561 in 2007 to +61.7886 in 2006 during the short rain season. Potato yield variability is also significant in both seasonal and annual trends ranging from -33.1369 in 2000 to +60.8892 in 2007 on the annual trend, -30.9963 in 2000 to +34.9898 in 2007 during the long rain season and -45.2353 in 2000 to +144.0588 in 2007 during the short rain season. Rainfall variations, lack of clean seeds and crop diseases have been found to be the major challenges facing potato production in the division. Forty five percent (45%) of the respondents see rainfall variation as the main cause of decreased potato yields 33% lack of clean seeds and 6% crop diseases. From the findings Pearson’s $r = 0.839$ is close to 1 showing that there is a strong relationship between rainfall trend and potato production. From the findings, the study recommends that soil and water management practices such as mulching, digging of trenches and earth dams and use of irrigation during the dry spell as adaptation measures should be applied to cope with rainfall variation. Farmers should be encouraged to enhance crop diversification to caution them from rainfall variability. They should practise crop intensification to increase potato production. The farmers’ field day organized by Farmers Training College should be done more frequently to enable more farmers to attend. The findings will benefit the Ministry of Agriculture, District Agriculture Officers, Kenya Agricultural Research Institute, and Agricultural Extension Officers, to mitigate seasonal variations of rainfall not only in Oljoro-orok but also in the entire Country.
CHAPTER ONE
INTRODUCTION

1.1 Background to the study problem

Agricultural sector faces many challenges stemming from weather variability, growing global populations, land degradation and loss of cropland to urbanization. Although food production has been able to keep pace with population growth on the global scale, there are serious regional deficits and poverty related nutritional deficiencies affecting close to a billion people globally in this century. Weather variability is affecting food production and availability in many parts of the world, particularly those most prone to drought and famine (Rosenzweig et al., 2002)

Weather variability has affected Irish potatoes (Solanum tuberosum) world’s fourth largest food crop following rice, wheat and maize respectively. Weather variability scenario studies performed using crop models show increases in potato yields in northern Europe and decreases or no change in the rest of Europe (Wolf, et al., 2000). Water and nutrient availability are the main factors that generally determine potato yields. Biological systems are based primarily on photosynthesis and thus dependant on incoming radiation. Irregular rainfall patterns results in high risk of drought and intra-seasonal dry spell, leading to low crop yields and sometimes total crop failure (Kinoti et al., 2010).

During the past decades, weather variability has had a marked influence on European agriculture (Orlandini et al., 2008, and Reidsma et al., 2009). The impacts of the 2003 heat wave in Europe, with temperatures up to 6°C above long-term
means and precipitation deficits up to 300 mm, resulted in an estimated loss of 13 billion Euros for the European agricultural sector (Ciais, 2005). Global climate model result shows that future heat wave in Europe will become more intense, more frequent and long lasting in the 21st century (Meehl and Tebaldi, 2004). Potatoes often respond nonlinearly to changes in their growing conditions and have threshold responses; this greatly increases the importance of weather variability and frequency of extreme events for yield, yield stability and quality (Porter and Semenov, 2005).

Weather variability, increased air temperature and carbon dioxide enrichment are projected to significantly affect crop phonology, reduce stomata conductance and transpiration, improve water-use efficiency and stimulate higher rates of photosynthesis (Drake et al., 1997, Chmielewski et al., 2004, Menzel et al., 2006, Kattge and Knorr, 2007). Seasonal patterns in agro-meteorological variables have a major impact on regional crop production (Wheeler et al., 2000, and Challinor et al., 2003). All of the processes involved in potato production take place at different spatial, temporal and organisational scales. Based on a long-term temperature analysis for Ukkel, the Belgian Royal Meteorological Institute (RMI, 2009) distinguished a first period (1910–1987) with an average mean temperature of 9.7°C followed by an abrupt rise in 1988 resulting in a second period with an average mean temperature of 10.9°C.

The impact of higher temperature leads to a longer growing season in temperate areas. A greater number of frost-free days per year lead to potato yields increase at high latitudes, including parts of Canada, Russia and Scandinavia. Winter cropping
is expected to increase annual potato yields in parts of Algeria, Morocco, China and South Africa (Harrison et al., 2000). Where rainfall and humidity increases, so too will the threat of potato diseases, such as late blight (*Phytophthora infestans*), especially when combined with longer growing seasons. Bacterial wilt may also increase as the weather changes, and potato pests, including disease carrying aphids will survive at higher altitudes (Onyango et al., 2010).

Another significant threat posed by rising global temperature is water stress as transpirations rates in potato plant increase, leading to greater demand from the soil. Without adequate rainfall or irrigation systems, crop failure is a real danger. Despite this, potato is likely to become more important for food security as temperature rise, since it has higher water productivity yielding more ‘crop per drop’ than rice, wheat and maize (Harrison et al., 2000).

Weather variables like temperature and precipitation are the important determinants of crop yields in Nepal (Maharjan, 2011). Increase in summer rain and maximum temperature has contributed positively to rice yield. Also, increase in summer rain and minimum temperature has positive impact on potato yields. However, increase in summer rain and maximum temperature adversely affected the yield of maize and millet. Increase in wheat and barley yield is contributed by current trend of winter rain and temperature (Maharjan, 2011).

In Africa agriculture constitutes a large share of her economies, with a mixture of subsistence and commercial production. African agriculture is sensitive to present
weather variations. The effects of weather variability are uncertain, but adverse impacts are likely in many regions. The future of African agriculture and food security depends on the outcome of weather variability, indigenous responses to global change, development efforts in the next few decades and global patterns of commodity production and demand (IPCC, 2007).

The Africa regions have distinct characteristics. North Africa and the Indian Ocean islands rely on irrigated agriculture. In West Africa, the gradient of climates from the Sahara to the humid coast determines the potential for agriculture. Subsistence agriculture and pastoralism dominate the Sudan and Sahelian regions; plantation agriculture is found along the Guinea coast. The highlands of East Africa are well known for potato production that takes advantage of the two rainy seasons. The lowlands, however, are subject to erratic rainfall and poor soils. The humid and sub-humid zones of Central Africa, where drought is problem, are conducive to roots and tubers (Maharjan, 2011).

The effect of rainfall variability on potato yields has been felt in Africa and beyond. The average potato yields in Sub Sahara Africa have remained stable at between 5-10 tons per hectare while those in Western Europe are over 30 tons per hectare (Kaguongo et al., 2007). Temperature changes triggers changes in other climate elements such as precipitation, wind and pressure systems. For example, increased rainfall in East Africa often causes floods that lead to displacement of people and destruction of properties. Severe drought has frequently affected sub Sahara Africa in the recent years. The human suffering that has accompanied these extreme events
provides an indication of the vulnerability of Sub Sahara African societies to rainfall variability. For example, in 1992, 20 million people in the region were in dire need of food relief because of drought; the same scenario was repeated in Zimbabwe, Mozambique, Kenya, Somalia and Ethiopia during the 2000’s. So what exactly is happening and what can be done to protect the potato? The impact of weather variability is manifested in floods, prolonged drought, unseasoned rains and extreme weather events, which create enormous developmental challenges for developing countries. This is due to the dependence on weather sensitive sectors such as rain-fed agriculture, pastoralism, forestry and wetlands (Chipanshi et al., 2003)

According to Mateche (2011) drought cycle in Kenya dates back to more than three decades ago. In 1975, widespread drought affected 16 000 people, in 1977 it was 20 000 people affected, in 1980, 40 000 people suffered the effects of drought, and in 1983/84 it hit over 200 000 people. In 1991/92 in Arid and Semi-Arid Districts of North Eastern Kenya, the Rift Valley, Eastern and Coastal Provinces, 1.5 million people were affected by drought. It was reported that widespread drought affected 1.4 million people in 1995/96 and in 1999/2000, famine affected close to 4.4 million people. In 2004, 3 million people were in dire need of relief aid for eight months from August 2004 to March 2005 due to widespread drought. The drought in 2008 affected 1.4 million people. In the late 2009 and early 2010, 10 million people were at risk of hunger after harvests failed due to drought.
Oljoro-orok division being one of the main Irish potatoes producing division in Nyandarua County necessitated the study on effect of rainfall variability on potato yields in the division.

1.2 Statement of the problem

Rainfall variability affect the ability to increase food production as required by the growing population in Kenya, creating a need to assess the rainfall characteristics that affect potato yields. It is not clear how these variations in potato yields are correlated to rainfall variations. Rainfall variability is a possible cause of the variations in the potato yield in Oljoro-orok division. It is against this background that the study investigated the relationship between rainfall variability and Irish potato production division.

1.3 Research questions

The study addressed the following questions:

i. What have been the seasonal and annual potato production and rainfall trends and variability between 1999 and 2009 in Oljoro-orok division?

ii. What is the relationship between seasonal and annual rainfall characteristics and potato production between 1999 and 2009 in Oljoro-orok division?

iii. What are the farmers’ adaptation measures to rainfall variability for potato production in Oljoro-orok division?
1.4 Research Hypotheses

This study was guided by the following null hypotheses;

H₀: Potato production have not varied seasonally and annually between 1999 and 2009 in Oljoro-orok Division.

H₀: There is no significant relationship between rainfall characteristics and potato production in Oljoro-orok Division.

1.5 Study Objectives

1.5.1 General objective

The general objective of this study was to investigate the relationship between rainfall variability and Irish potato production in Oljoro-orok division.

1.5.2 Specific objectives

i. To assess the seasonal and annual rainfall and potato production trends and variability between 1999 and 2009 in Oljoro-orok division.

ii. To analyse seasonal and annual rainfall characteristics and correlate them with potato production in the division.

iii. To evaluate farmers adaptation measures to rainfall variability for potato production in Oljoro-orok division

1.6 Justification and significance

Oljoro-orok division was selected because it is one of the major Irish potato growing divisions in Nyandarua County. Of the approximately 100,000 ha of land under Irish potato cultivation in Kenya, 17,500 ha (17.5%) are located in Nyandarua County (Jaetzold et al., 2007). Effects of rainfall variability have been felt in many regions
in Kenya thus leading to low food supply and death of livestock in humid and semi-arid regions. According to Metz et al. (2007) research is required on linkage between rainfall variability and potato yields. This study will provide an understanding of the relationship between rainfall characteristics and rainfall variability and farmers’ adaptation measures to rainfall variability for potato production in Oljoro-orok that will lead to high yields hence improving the family livelihoods of the area. The study will significantly benefit the Ministry of Agriculture, District Agriculture Officers and Kenya Agricultural Research Institute, Agricultural Extension Officers, Farmers Training Centre, farmers’ policy makers and policy implementers in trying to mitigate seasonal variations of rainfall in the entire country.

1.7 Scope and limitation of the study

There are many factors that affect potato yields, such as lack of clean seed, lack of water and nutrients in the soil, damage from pest and diseases and changes in the weather patterns (Ogola et al., 2011). Weather variables encompass variables such as rainfall, temperature, wind, humidity and sunshine among other. The study considered rainfall as the most critical element that influences potato production. Primary data was collected from randomly selected farmers through questionnaire. Secondary data on rainfall and potato yields was collected from Nyahururu Meteorological Station and District Agriculture Office respectively. The data collected was for the period between 1999 and 2009. The period was chosen because it is the interval between 1997/1998 El Niño rains and 2009 when the Kenya Meteorological Department had predicted El Niño phenomenon in Kenya. In
1997/1998 El Niño rains, farmers received low Irish potato yields with a lot of post harvest losses. The yields were also low in the predicted 2009 El Niño rains and therefore the study assessed rainfall characteristics and their effect on potato yields in the division. In the process of data collection some respondents were reluctant to fill the questionnaires; this was a limitation in relation to accuracy of data.
CHAPTER TWO
LITERATURE REVIEW

2.0 Introduction

This section reviews literature in the following categories: The relevant studies on climate and weather variability on potato yields, rainfall trends and characteristics and potato yields, effects of non-weather variables on potato yields and challenges facing potato production.

2.1 Climate and Weather Variability

Long-term climate change has significance to global food production. Extreme weather events and their year-to-year variability pose great risk to food security globally. Historically, many of the largest reductions in crop productivity have been attributed to anomalously low precipitation events (Kumar et al., 2004; Sivakumar et al., 2005). However, even small changes in mean annual rainfall can impact on productivity. Lobell and Burke (2008) report that a change in growing seasonal precipitation by one standard deviation can be associated with as much as a 10 per cent change in production (e.g. millet in South Asia). Indian agriculture is highly dependent on the spatial and temporal distribution of monsoon rainfall (Kumar et al., 2004).

Asada and Matsumoto (2009) analysed the relationship between district-level crop yield data (rainy season ‘kharif’ rice) and precipitation for 1960–2000. It was shown that different regions were sensitive to precipitation extremes in different ways. Crop yield in the upper Ganges basin is linked to total precipitation during the
relatively short growing season and is thus sensitive to drought. Conversely, the lower Ganges basin was sensitive to pluvial flooding and the Brahmaputra basin demonstrated an increasing effect of precipitation variability on crop yield, in particular, drought. These relationships were not consistent through time, in part owing to precipitation trends. Variation between districts implied the importance of social factors and the introduction of irrigation techniques.

Meteorological records suggest that heat waves became more frequent over the twentieth century, and while individual events cannot be attributed to climate change, the change in probability of heat waves can be attributed. Europe experienced a particularly extreme climate event during the summer of 2003, with average temperatures reaching 6°C above normal and precipitation deficits of up to 300 mm. A record crop yield loss of 36 per cent occurred in Italy for corn grown in the Po valley where extremely high temperatures prevailed (Ciais et al., 2005). It is estimated that such summer temperatures in Europe are now 50 per cent more likely to occur as a result of anthropogenic climate change (Stott et al., 2004).

As current farming systems are highly adapted to local climate, growing suitable crops and varieties, the definition of what constitutes extreme weather depends on geographical location. For example, temperatures considered extreme for grain growers in the UK would be considered normal for cereal growers in central France. In many regions, farming may adapt to increases in extreme temperature events by moving to practices already used in warmer climate, for example by growing more tolerant crops. However, in regions where farming exists at the edge of key
thresholds, increases in extreme temperatures or drought may move the local climate into a state outside historical human experience.

Weather variability is already exerting control over development progress, including efforts to address food security and poverty alleviation in sub-Saharan Africa (Sokona and Denton, 2001). On many occasions extreme weather variability events leave vulnerable people in Africa and indeed in other regions of the world totally unprepared and unable to cope. The adverse impact of climate change is further envisaged on natural resources such as water and land. These resources are threatened by poor and unsustainable resources management, on one hand and the impact of weather variability on the other. Between 1961-1990 and 2040-2069 the global (terrestrial excluding Antarctica) average temperature is predicted to increase between 2.1°C and 3.2°C (Hijmans, 2003) depending on various climate scenarios.

The temperature increase is smaller when changes are weighted by the potato area and particularly when adaptation of planting time and cultivars is considered (a predicted temperature increase between 1 and 1.4°C). He further argues that, global potential potato yield decreases by 18% to 32% (without adaptation) and by 9% to 18% (with adaptation). At high latitudes, global warming will likely lead to changes in the time of planting, the use of late-maturing cultivars, and a shift of the location of potato production. In many of these regions, changes in potato yield are likely to be relatively small, and sometimes positive. Shifting planting time or location is less feasible at lower latitudes, and in these regions global warming could have a strong
negative effect on potato production. It is shown that heat-tolerant potato cultivars could be used to mitigate effects of global warming in (sub) tropical regions.

Higher growing season temperatures can significantly impact agricultural productivity, farm incomes and food security (Battisti and Naylor, 2009). In mid and high latitudes, the suitability and productivity of crops are projected to increase and extend northwards, especially for cereals and cool season seed crops (Maracchi et al., 2005). Crops prevalent in southern Europe such as maize, sunflower and soya beans could also become viable further north and at higher altitude (Olesen and Bindi, 2002). Here, yields could increase by as much as 30 per cent by the 2050s, depending on crops (Audsley et al., 2006).

Fisher et al. (2006) simulated large gains in potential agricultural land in the coming centuries. The gains are for regions such as the Russian Federation, owing to longer planting windows and favourable growing conditions under warming, amounting to a 64 per cent increase over 245 million hectares by the 2080s. However, technological development could outweigh these effects, resulting in combined wheat yield increases of 37–101% by the 2050s (Ewert et al., 2005). Even moderate levels of weather variability may not necessarily confer benefits to agriculture without adaptation by producers, as an increase in the mean seasonal temperature can bring forward the harvest time of current varieties of many crops and hence reduce final yield without adaptation to a longer growing season.
In areas where temperatures are already close to the physiological maxima for crops, such as seasonally arid and tropical regions, higher temperatures may be more immediately detrimental, increasing the heat stress on crops and water loss by evaporation. A 2°C local warming in the mid-latitudes could increase wheat production by nearly 10 per cent whereas at low latitudes the same amount of warming may decrease yields by nearly the same amount. Different crops show different sensitivities to warming. It is important to note the large uncertainties in crop yield changes for a given level of warming. By fitting statistical relationships between growing season temperature, precipitation and global average yield for major crops, Lobell and Field (2007) estimated that warming since 1981 has resulted in annual combined losses of 40 million tonne or US$5 billion (negative relationships between potatoes, wheat, maize and barley with temperature).

Ojanpera et al. (2002) assessed the effect of weather conditions on tubers yield (Solanum tuberosum) in the European ‘CHIP’ experiments. Analysis of the soils used during the experiments demonstrated that in most cases sufficient nutrient elements were available to guarantee an undisturbed growth. Mean concentrations of CO$_2$ in ambient air and in different treatment illustrated the observed variability of trace gas exposures between different sites and experiments. Comparison of marketable tuber yields revealed an increase at higher latitudes. The results were associated with lower temperature and longer day’s lengths at the higher latitudes, which in turn were associated with longer growing seasons.
Nyongesa et al. (2008) examined the tolerance of potato with changes in temperature. The study revealed that in Kenya there are varieties of potatoes which have previously been doing well in certain regions but because of the rising temperatures new varieties that cope with these changes have been discovered. Unlike the study that examined the effect of temperature on potato yield the present study assessed the effects of onset and cessation of rainfall on potato yields in Oljoro-orok division.

According to Lanyasunya et al. (2006) livestock feed availability, quality and herd performance on smallholder farms in Oljoro-orok is highly seasonal dependent. The study attributes the observed lower performance of lactating cows in dry season to feed inadequacy (quantity and quality). It is, however, possible to reduce production losses through protein supplementation (using farm grown high quality legumes). Provision of non-protein nitrogen (NPN) through treatment of crop residues with Urea/alkali or feeding poultry litter is also important options to bridge protein deficiency gaps on farm. Finally, in order to improve ruminant livestock production, future research and development should therefore focus exploring these and other feasible options so as to sustainably enhance both feed quality and quantity on smallholder resource-poor dairy farms. Unlike the study that looked at effects of seasonality on feed availability the present study looked at the effects of number of rainfall days on potatoes in Oljoro-orok division.

According to Olanya et al. (2004) late blight and bacterial wilt were regarded by farmers in Nyandarua as the most common diseases. The farmers interviewed were
aware of late blight and had experienced it in their farms. More than half of the farmers surveyed (54%) reported late blight as being a serious problem on their farms. Unlike the study that looked at management of potato late blight in Kenya highlands, the present study assessed the effects of rainfall variability on potato yields in Oljoro-orok division.

2.2 Non-weather variables

According to Obare et al. (2010) Irish potato production in Oljoro-orok is characterised by decreasing returns to scale with a mean allocative efficiency of 0.57. Substantial productivity gains can be obtained by improving the allocative efficiency of Irish potato producers. To achieve this, the government and stakeholders in the Irish potato sector should attempt to create a favourable institution environment that would facilitate the farmers’ access to formal credit.

According to Ministry of Agriculture (2007) increase in potato production occur simultaneously with increase production of cereals and other staple crops, principally maize, largely attributable to average rainfall in areas of cereal production. The increase in maize in 1998 was especially notable given action taken by the Kenyan Government to encourage maize production, via tariffs on imported maize that might otherwise be more cheaply available to consumers thus encouraging farmers to put more land under maize (Nyoro, 2002).

According to Moock (1973) the withdrawal of household labour through male to labour migration, off-farm employment and school participation of children have led
to major changes in the structure of the division of labour. One of the consequences of these processes is the expansion of women's roles in reproduction and production. The study showed that women in western Kenya make a significant contribution to agricultural production. They are very heavily involved in crop production and household activities. Their involvement in livestock production is culturally defined and structurally circumscribed even though when the children and male heads of household are away, women combine livestock activities with their traditional responsibilities.

According to McCalla (1994) and Young (1999), new lands that can be put under agriculture are limited, contrary to the last three decades, where the bulk of food production in Sub-Saharan Africa came from expansion of agricultural lands. The opportunities to increase crop yields under rain-fed agriculture strongly rest on focusing our attention on maximizing yield per unit of water applied. In order to formulate and adopt appropriate and adequate options for increasing productivity in rain-fed agriculture, it is worthwhile to have an understanding into the performance of this sector from trends analysis of the productivity of potato cultivated under rainfall. Such insight enabled the study to evaluate possible factors that dictate productivity of potato in rain-fed agriculture division like Oljoro-orok.

According to Kuyiah (2007) cash constraints and small land sizes are the two most important factors that inhibit realization of higher farm incomes and optimal production at farm level. There is need for policies that spur investment in public infrastructure, rural financial markets, private investment, and support institutions to
address the problems of high transaction costs to investors, and reduce risks faced by farmers.

2.3 Rainfall trends and potato yields

Studies indicate that the condition in the Indian Ocean might also affect rainfall variability in Indonesia. Like Pacific Ocean, Indian Ocean also has phenomenon like El Niño, called Indian Ocean Dipole or IOD (Saji et al., 1999). A warm pool in the Indian Ocean moves eastward in a cycle of 3 to 7 years. This IOD will affect both the zonal (east-west) circulation in the troposphere, and in the meridional (north-south) circulation (Yamagata et al., 2001).

Variability of potato yield depends on rainfall variability in Bandung district in China, as rainfall is the main source of water for crop growth. Most of agriculture areas at Bandung district are rain-fed, except rice growing area around Bandung City which is mostly irrigated. However, the area located at the end tail irrigated system is very prone to drought. In El-Niño years, the second crops were normally suffering from drought due to lack of irrigation water and rainfall during this period (April-September) was normally very low. Variability of rainfall at Bandung district is significantly correlated with global climate forces, SOI (Southern Oscillation Index) and IOD (Indian Ocean Dipole), particularly dry season rainfall. The relationship is consistently positive with SOI and consistently negative with IOD. Further analysis suggested that the linear effect of IOD was not significant in all stations, but the interaction effect of the SOI and IOD was significant in some of the stations (Boer, 2004). Unlike the Indian rainfall variability which is significantly correlated with
SOI and IOD the East African rainfall is affected by El Niño phenomena hence the current study evaluates trend and variability of rainfall on potato yields in Oljoro-orok division.

According to Adeniyi (2009), Nigeria rainfall follows a usual zonal pattern and the vast majority of precipitation falls within a well-defined period. The southern stations (Calabar, Enugu, Ibadan, Ogoja, Port-Hacourt) are characterized by two peaks of rainfall in June/July and September while the northern stations (Os, Maiduguri, Minna, Nguru and Sokoto) have only one peak per year. Rainfall starts earlier in the southern stations in April/May and it ceases last in this region in October. A period termed “August break” exists in the south when rainfall ceases for some days. The period of rainfall in the northern stations is 3 to 5 months; the onset month is May/June while the cessation month is September/October. The coastal stations receive more rainfall (ranging from 1487.9 to 2865.2 mm) than the inland stations (ranging from 473.3 to 836 mm) annually. Total annual rainfall pattern in Nigerian stations has a seemingly random variation, while some years have rainfall amount far below the mean, some have amount of rainfall far above the mean and can be termed years of drought or flood, respectively, depending on the magnitude of deviation from the mean. Years of average, low (drought) and high (flood) amount of rainfall are determined. Many of the points lie very close to and within the confidence limits with the exception of the ENSO years. The points far above the confidence limits are the flood years associated with the neutral and cold phases of ENSO the points far below the confidence limits are the drought years which
correspond to the warm ENSO phase. Rainfall variability which is correlated to global phenomena such as ENSO affects rain-fed Agriculture.

According to Muga (2010) increased variability (deviation from the mean) of crop production is also a major concern of farmers in Eastern Africa. Inter-annual climate variability (ENSO) has huge impacts on the region’s climate. Warm ENSO events also referred to as El Niño events produce abnormally high amounts of precipitation in parts of equatorial East Africa and result in flooding and decreased agricultural yields.


Kabanda (2011) on potato production trends in South Africa between 1991 and 2003 found that dry land potato production was leading in 1991. The production was 50.8 percent from dry land farming against 49.2 percent of irrigated land. However, by 2002/3 the dry land farming has shrunk to approximately 22 percent while irrigation increased to the tune of 78 percent. The high production costs compelled the introduction of irrigation technology by farmers to manage high risks and price fluctuations characteristic of dry land potato production. It was observed that in
2002/2003 there was a decline in irrigated hectares planted with potatoes as farmers shifted to maize because of the higher prices of maize at that time.

The potato yields in Nyandarua vary depending on the variety. Nyayo, the most popular variety exhibits an average yield of 7.7 tons per hectare (CIP, 2005). According to Kaguongo et al. (2007) the four most frequently grown varieties were Nyayo, Tigoni, Tana Kimande and Ngure. The four varieties are white skinned. The study noted that although high proportion of sampled farmers in Nyandarua grew Nyayo the total area under Tigoni was larger than the area under Nyayo. Ngure was the second important in terms of production area followed by Nyayo. Unlike the study which was looking at the popular potato variety the present study assessed the challenges and opportunities facing these varieties in Oljoro-orok division.

2.4 Rainfall characteristics and potato yields

Water is vital to plant growth, so varying precipitation patterns have a significant impact on agriculture. As over 80 per cent of total agriculture globally is rain-fed, projections of future precipitation changes often influence the magnitude and direction of climate impacts on crop production (Olesen and Bindi 2002; Tubiello et al., 2002; Reilly et al., 2003).

Ronsezweig (2002) examined the potential impacts of weather variability on citrus and potato production in the US. The study identified that potato production is vulnerable to an increase in temperature in the northern states; while increased CO₂ and changes in planting date having minimal compensating impacting on simulated
potato yields. Unlike the study which examined the effects of CO$_2$ and temperature, the present study assessed the effects of rainfall variation on potato yields. The impact of global warming on regional precipitation is difficult to predict owing to strong dependencies on changes in atmospheric circulation, although there is increasing confidence in projections of a general increase in high-latitude precipitation, especially in winter, and an overall decrease in many parts of the tropics and sub-tropics (IPCC 2007). One scenario which predicts an overall increase in precipitation shows large increases in southern USA and India but also significant decreases in the tropics and sub-tropics.

About 95% of current world population growth occurs in tropical developing countries with rural economies based on rain-fed agriculture (Rockstrom et al., 2001). In Sub-Saharan Africa, rain-fed agriculture has been the dominant source of food production. It is likely to remain so for the foreseeable future, since more than 95% of the agricultural farmland is under rain-fed agriculture (Parr et al., 1990 and Rosengrant et al., 2000).

The common characteristics of rain-fed agriculture, especially in the tropical and the semi-arid agro ecosystems are low crop yields far below potential yields attainable in the regions, and high on-farm water losses. For example, in tropical and semi-arid Sub-Saharan Africa, cereal yields from rain-fed cultivation have been reported to be generally around 1 ton ha$^{-1}$ (Rockstrom, 2001) as against potential yields attainable in the region, which are reported as 3-5 ton ha$^{-1}$ (Barron, 2004). This wide yield gap
suggests that there is an enormous opportunity to raise crop yields of rain-fed agriculture.

According to Adeniyi (2009) the long term onset time of rainfall is normally used to determine the time of farm clearing and preparation for planting. Following the method of onset determination proposed by the study on measures of uncertain climatic condition in Nigeria. The onset time of rainfall for each year can be specified and time of planting of potatoes can be determined to get maximum yield. The known annual cycle of rainfall gives the range of expected amount of rainfall for each year, so the farmers can know the type of plant that can survive under such amount of rainfall.

Watson et al. (2004), analysed potato productivity in farmer’s fields in Bolivia. The study identified seasonal changes as a major problem affecting potato yields in Bolivia, rains that used to arrive in October now come in December, but the rainy season still only lasts until March, meaning a shorter growing season. Potato farmers have traditionally hedged their bets by growing a number of different varieties in the hope of a better chance of a good harvest. Now, heat-tolerant potato varieties will become an essential weapon in their armory. Potato hybrids are one promising response to the threat of weather variability. Unlike the study which focused on shift in the planting season, the current study assessed the effect of rainfall characteristics such as rainfall amount, onset and cessation of rainfall and number of rain days on potato yield and evaluated farmers’ adaptive capacity for potato production in Oljoro-orok division.
2.5 Challenges facing potato production

According to Kabira (2002) marketing is one of the biggest problems facing most potato growers in Nakuru district. The major problem facing the farmers is one of low producer prices, a common feature at each harvest. The poor prices have a negative consequence including low input use and poor crop husbandry practices resulting in low harvest yields. Middlemen usually buy potatoes from farmers for selling to various markets. These traders are seen as a necessary evil exploiting the growers yet helping them market the surpluses both within Nakuru and in distant markets such as Tanzania, Uganda, Nairobi and Mombasa.

Despite the efforts directed at improving potato production in Kenya over the years low productivity still remains a major challenge in the sub sector. The average national farm level yields of 7.3 mt/ha compares unfavourably with a potential of 14.5 – 20 mt/ha under farm level conditions and those from research station of 25-35 mt/ha (KARI, 2005). The diminishing potato yields, are as a results of many factors such as, lack of water and nutrients in the soil, damage from pest and diseases and changes in the weather patterns (Kinyua et al., 2001). Unlike the study that assessed the effects of lack of water and nutrients in the soil, damage from pest and diseases the current study identified lack of uniformity in soil, lack of clean seeds, inadequate field officers, high cost of farm inputs and soil degeneration as the key challenges affecting potato yields in Oljoro-orok division.
In conclusion the literature review lays the ground for addressing rainfall variability that leaves potato farmers vulnerable to rainfall variability. Rainfall variability and agriculture are interrelated processes both of which take place on global scale. The variables affecting agriculture include: temperatures, rainfall, humidity, carbon dioxide, wind, assets, seed availability and quality, access to information, education, gender, transport, and market (IPCC, 2007). These conditions determine the carrying capacity of the biosphere to produce enough food for the human population. Since rainfall variability presents challenges on many fronts it requires robust responses from potato growers and research organizations where the present study falls. The findings on farmers’ adaptation strategies will contribute towards refinement of policies to deal with rainfall variability on potato farming.

2.6 Conceptual Framework

From Figure 2.1 weather variables and their variability affect potato growth and consequently potato yields. In Oljoro-orok rainfall constitutes the main water source for plants. Rainfall characteristics such as rainfall amount, onset and cessation of rainfall, number of rain days, rainfall distribution and rainfall intensity affect potato production. The rainfall characteristics determines the adaptive capacity to be applied such as farm level decisions on the appropriate time of planting, the methods of farming and sustainable land management practices such as mulching, digging trenches and irrigation to be put in place in a growing season. Intervening factors such as weather forecast, scientific methods of farming, seed quality and availability fertilizer application are important to improve yields. The intervening factors inform farmers on the time of planting, nature of seed to be planted and the possible threats
such as pest and diseases which affect potato yields. The adaptive capacity and intervening factors depends on the socio-economic factors such as the education of the farmers for educated farmers’ are more receptive to new ideas and fast in decision making. Land tenure system is also a factor that adaptive capacity and intervening factors have to depend on for farming to take place. Transport and communication enable farmers receive planting materials on time and also the information on the onset and cessation of rainfall. Rainfall characteristics linked to, intervening factors, adaptive capacity and socio-economic factors leads to potato yields.
Figure 2.1 Conceptual Framework for analyzing potato yield (Source: Synthesis of literature by Author, 2011)
CHAPTER THREE

RESEARCH METHODOLOGY

3.0 Introduction

This chapter deals with procedures and methods the researcher used in order to obtain and analyse the data. The chapter entails the description of the study area, the target population, the sampling procedures, the data collection procedures and methods of data analysis and interpretation.

3.1 Study area

The study area was Oljoro-orok division, Nyandarua County situated in the central part of Kenya. The division lies between Latitude 0° 8’ north and 0° 40’ south and between 35° 13’ east and 36° 22’ east between the Rift Valley and Aberdare Ranges as shown in Figure 3.1 (Nyandarua District Strategic Plan, 2010). The division falls within the central highlands with an altitude range of between 2300 and 3000m above sea level. The mean temperature of the area is 22°C with a mean annual rainfall of 1000 mm. Land ownership is predominantly freehold. The majority of the farms in the area are small scale. Soil is not uniform in the division, the upper zone of the division namely Oraimutia and Nyairoko locations have the black cotton soils. The lower zone of the division namely Lesirko and lower side of Oraimutia locations have the laterites soils. Land size per household varies across the divisions but with an average of 2 hectares (Jaetzold, et al., 2007). The growing seasons are largely determined by rainfall patterns. In Oljoro-orok there are two distinct rain seasons occurring between February-June and October – December (Kaguongo, et al., 2007). Irish potato is planted in both seasons of the year and takes between 90
and 120 days to mature. Oljoro-orok division and has 3470 total households (KNBS, 2009). Farming is the main economic activity within the division. Potatoes are the major cash crop in the division. Farmers in Oljoro-orok sell their produce to middlemen who transport the potatoes to major markets in Nairobi, Nakuru and Mombasa.
Figure 3.1 Map of the study Area (Oljoro-orok Division map)
Source: Nyandarua west District Agriculture office (2012)
3.2 Target population

Population refers to an entire group of person or element that has at least one thing in common (Kombo and Tromp, 2009). The researcher purposely targeted 300 farmers household believed to be reliable for the study in the three locations of Oljoro-orok division.

3.3 Sampling procedure

The study employed purposeful sampling design; this approach seeks to collect data from 10% of the total population (Neumann, 2000). Neumann (2000) suggests 10% as an adequate sample. The main factors to consider in determining the sample size is the need to have it manageable enough and derive detailed data at an affordable cost in terms of time, finances and human resource (Neumann, 2000). The population was 3000 farmers household in Oljoro-orok division (KNBS, 2009) and in this regard 10% translated to 300 households. Areas were clustered into location forming the basis of selecting the sample population in each Location. The sample in each location was computed based on the population proportion using equation 1.

**Formula for calculation of sample size for each location**

\[ n = \frac{p}{\mu} \times 300 \]  

Where;

- \( n \) is the sample population of the division.
- \( n = 82 \) Oraimutia Location
- \( n = 48 \) Nyairoko Location
- \( n = 170 \) Lesirko Location
- \( P \) is the population of the household in the location
- \( \mu \) is the total households in the division
3.4 Pilot Study
A pre-field visit was conducted to seek permission from the district commissioner and the district officer where the study was conducted. The district agriculture officer, division agriculture officer, the officer in-charge of the Kenya Agriculture Research Institute and Nyahururu Meteorological Station were visited so as to introduce oneself and also get acquainted with officials that were used in conducting the study. Sampling of the farmers households was done during this period. The pilot study was also used to acquaint the researcher with the study area so as to be able to identify and recruit research assistants. The study also involved pre-testing of a sample of questionnaire so as to determine their reliability.

3.5 Data collection procedures

3.5.1 Field data collection
Data collection was carried out during a one-month fieldwork period between 1st November, 2011 and 2nd December 2011. Both Qualitative and quantitative data were collected.

3.5.2 Primary data
Primary data was collected from randomly selected farmers in the area through questionnaires. A questionnaire containing both structured and unstructured questions (Appendix A1) was administered on the selected farmers in the three locations, namely Oraimutia, Lesirko, and Nyairoko.
3.5.3 Field data collection plan

A field data collection plan was made during the fieldwork preparation period. The plan outlined pre-fieldwork activities, the data collection schedule to be followed, the data collection methods to be used and the resources to be spent during the fieldwork. Two data collection assistants were contacted and recruited before the commencement of fieldwork.

3.5.4 Administration

The questionnaires were targeted at farmers. The distribution of the questionnaires was done randomly by hand to the respective respondents and given about one week to complete them. This mode of distribution gave the respondents ample time to complete the questionnaires. The questionnaires were completed on a voluntary basis and the respondents were free to determine the extent to which they would participate in the questionnaire survey (e.g. respondents could complete one or both parts of the questionnaire).

3.5.5 Response rate

From the data obtained, 300 questionnaires were administered, 192 were filled and returned. This represented 65% response rate, which is considered satisfactory to make conclusions for the study. This high response rate can be attributed to the data collection procedures, where the researcher and two trained research assistants administered questionnaires and picked the filled questionnaires. According to
Mugenda and Mugenda (2003) a 50% response rate is adequate, 60% good and above 70% response rate very good.

3.5.6 Secondary data collection

The data was collected during a one-month fieldwork period between 1\textsuperscript{st} November, 2011 and 2\textsuperscript{nd} December 2011. Secondary data on rainfall and potato yields was collected from Nyahururu Meteorological Station and District Agricultural office respectively. Potato yield data collected was for both long rain season and short rain season between 1999 and 2009. The long rain season yields were added to the short rain season yield to get the annual yields in each year. The data collected was from the seasonal data recording sheets found at the division agriculture office. The recording sheet captures the number of hectares planted in a growing season, expected yields and the actual yields realised at the end of the season. Monthly rainfall data was collected between 1999 to 2009. Rainfall data collected had the following rainfall characteristics; rainfall amounts, number of rainy days and onset and cessations. The rainfall data was collected from the rainfall recorded at Nyahururu Meteorological Station where daily, monthly and annual rainfall is captured.

3.5.7 Verification and validation of data

Discussions were held with the respondents of the questionnaire survey to address any unclear issues in the questionnaire. Additional discussions were arranged with officers from the district Agriculture office on a range of issues concerning
potato yields and the farmers’ practices in the area. The targets for these discussions were public officials and experts with knowledge and experience in potato cultivation. The methods used for field data validation included: ensuring that key definitions and concepts are as clear as possible. Thorough background literature review was conducted before, during and after the fieldwork period. Explaining the objectives of the research and the potential of the research to improve the existing situation and involving the individual farmers to providing data as much as possible in the data collection process

3.6 Data analysis procedures

Trend and variability test were carried out on seasonal and annual rainfall and potato yield data between 1999 and 2009 in Oljoro-orok division. Simple line graphs on seasonal and annual rainfall and potato yield were computed and the trend line drawn to determine the significance of the trend. Trend analysis was done to determine the relationship of rainfall and potato yield data in Oljoro-orok division. Both annual and seasonal trends of rainfall and potato yield data were analysed. Seasonal and annual variability indices of both rainfall and potato yield were computer using equation 2.

Formula for calculation of relative variability

\[
RV = \frac{X - \bar{X}}{\bar{X}} \times 100
\]  

(2)

Where;  
RV is relative variability,  
X is the data element and  
\( \bar{X} \) Is the mean of the data.
Correlation analysis was done on rainfall characteristics and potato yield data to determine the relationship between the two variables. To determine significance of the test obtained correlation value was compared with the p-value at 5% level of significance. In the event that the obtained correlation value was greater than the p-value, the null hypothesis was rejected. If the calculated correlation value was less than the p-value, the null hypothesis was accepted. The correlation analysis was computed by the formula 3.

**Formula for computing correlation**

\[
    r = \frac{\sum XY - \frac{\sum X \sum Y}{N}}{\sqrt{\left(\sum X^2 - \frac{(\sum X)^2}{N}\right)\left(\sum Y^2 - \frac{(\sum Y)^2}{N}\right)}}
\]

(3)

A SWOT analysis was done to evaluate the available information concerning the farming environment in order to identify internal strengths and weaknesses, and external Threats and Opportunities. Strengths are internal attributes within the division that are helpful to achieving its increased potato production. Weaknesses are internal attributes within the division that are harmful to achieving increased potato production.

Opportunities are external conditions that are helpful to achieving increased potato production. Opportunities are outside conditions or circumstances that the division could turn to its advantage, and could include a specialty niche skill or technology that suddenly realizes a growth in broad market interest.
Threats are external conditions that are harmful to achieving increased potato production. Threats are current or future conditions in the outside the division that may harm potato production. The data was analysed using statistical software namely SPSS version 17 and SAS for windows version 8. Frequencies, percentages and proportions were used in interpreting the respondents’ perception of issues raised in the questionnaire. The data was presented using tables, line and bar graphs, pie-charts and proportional circles.

3.7 Ethical Consideration
Research ethics were upheld at all stages of the research period. Honesty and objectivity prevailed when collecting, analyzing, interpreting and presenting data. Information obtained from respondents was treated with great care and confidence.
CHAPTER FOUR
RESULTS AND DISCUSSIONS

4.0 Introduction

The purpose of this chapter is to discuss the results of the findings and interpret data gathered in the study. The discussion is structured into three main sections with each showing the findings based on a specific objective. The first section discusses the trend and variability of rainfall and potato production. The second section discusses the seasonal and annual trends of rainfall and potato yields and correlation of rainfall characteristics and potato yields. The third section covers strengths, weaknesses, opportunities and threats facing potato production in Oljoro-orok.

4.1 Trends of Rainfall

4.1.1 Trend of annual rainfall

The results in Figure 4.1, shows that annual rainfall amount has increased between 1999 and 2009 in Oljoro-orok division as shown by the trend line. Peaks are noticed in 2001 and 2007 while dips are noticed in 2000 and 2009. The peak in 2001 is as a result of favourable rainfall during the long rain season in that year as shown by Figure 4.2. The peak in 2007 was as a result of favourable rainfall especially during the long rain season in that year as shown by Figure 4.2. The dips in 2000 and 2009 are as a result of unfavourable rainfall during the long rain season in the same period as shown by Figure 4.2. The short rain season data contributes a lot to the increasing trend on the annual rainfall since as shown on Figure 4.2, rainfall trend shows a decreasing during the long rain season. $R^2=0.075$ shows that strength of the line is weak. The findings supports the argument that, ‘Year to year and season to season
rainfall variability is persistent in East Africa, a phenomenal that continue to present a challenge to agriculture production (Shisanya, 1996; Seleshi and Zanke, 2004).

**Figure 4.1: Annual Rainfall data trend for years 1999 – 2009**

**4.1.2 Trend of seasonal rainfall during the Long rain season**

The result in the Figure 4.2 shows a decreasing trend of rainfall between 1999 and 2009 during the long rain season. Peaks are noticed in the year 2001, 2003 and 2007 while dips are noticed in 2000, 2002, 2008 and 2009. The peaks were as a result of favourable rainfall in the season while the dips were as a result of unfavourable rainfall in the season. The variation of rainfall in Oljoro-orok as the study found is supported by IPCC (2007) argument that rainfall variation in East Africa is as a result of the El Niño phenomena. This argument is also supported by Boer (2004) that variability of rainfall at Bandung district is significantly correlated with global
climate forces, SOI (Southern Oscillation Index) and IOD (Indian Ocean Dipole). The El Niño, SOI and IOD are global phenomena that have large scale climatic effects.

![Figure 4.2: Trend of Rainfall (mm) data: 1999-2009 – Long rain season](image)

**Figure 4.2: Trend of Rainfall (mm) data: 1999-2009 – Long rain season**

### 4.1.3 Trend of seasonal rainfall during the Short rain season
The trend line in the Figure 4.3 shows that rainfall during the short rain season increased between 1999 and 2009 in Oljoro-orok division. Peaks are noticed in 2002, 2006 and 2009 while dips are noticed in 1999, 2003, 2005, and 2007. The peaks are as a result of high rainfall in the season while the dips are as a result of low rainfall in the season. \( R^2 = 0.1443 \) shows that the strength of the line is weak.
4.2 Rainfall Variability

Rainfall variability was computed using rainfall variability index. Annual rainfall variability ranges from +48.9891 in 2007 to -34.898 in 2000 as shown in Table 4.1. Rainfall variability is significant in the long rain season trend and ranges from +105.7627 in 2007 to -61.01695 in 2008 as shown in Table 4.1. Rainfall variability is also significant in the short rain season trend and ranges from +61.7886 in 2006 to -69.7561 in 2007 as shown in Table 4.1.

Figure 4.3: Trend of Rainfall (mm) data: 1999-2009 – short rain season
Table 4.1: Seasonal and annual rainfall variability index

<table>
<thead>
<tr>
<th>Year</th>
<th>Annual rainfall amount</th>
<th>Annual rainfall variations mean=949.13</th>
<th>Seasonal rainfall amount -long rain</th>
<th>Seasonal rainfall variation-long rain mean=590</th>
<th>Seasonal rainfall amount -short rain</th>
<th>Seasonal rainfall variation-short rain mean=246</th>
</tr>
</thead>
<tbody>
<tr>
<td>1999</td>
<td>786.6</td>
<td>-17.1241</td>
<td>649</td>
<td>10</td>
<td>11.4</td>
<td>-51.6260</td>
</tr>
<tr>
<td>2000</td>
<td>617.9</td>
<td>-34.898</td>
<td>428</td>
<td>-27.4576</td>
<td>311.9</td>
<td>26.8293</td>
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<tr>
<td>2001</td>
<td>1187.3</td>
<td>+25.0935</td>
<td>817</td>
<td>38.4746</td>
<td>246.4</td>
<td>0.1626</td>
</tr>
<tr>
<td>2002</td>
<td>961.5</td>
<td>+1.3033</td>
<td>413</td>
<td>-30</td>
<td>343.2</td>
<td>39.4309</td>
</tr>
<tr>
<td>2003</td>
<td>905.9</td>
<td>-4.5547</td>
<td>707</td>
<td>19.8305</td>
<td>104</td>
<td>-57.7236</td>
</tr>
<tr>
<td>2004</td>
<td>907.2</td>
<td>-4.4177</td>
<td>530</td>
<td>-10.1695</td>
<td>195</td>
<td>-20.7317</td>
</tr>
<tr>
<td>2005</td>
<td>890.7</td>
<td>-8.8649</td>
<td>515</td>
<td>-12.7119</td>
<td>174.3</td>
<td>-29.1463</td>
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<tr>
<td>2006</td>
<td>1058.5</td>
<td>+11.5232</td>
<td>650</td>
<td>10.1695</td>
<td>398</td>
<td>61.7886</td>
</tr>
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<td>2007</td>
<td>1414.1</td>
<td>+48.9891</td>
<td>1214</td>
<td>105.7627</td>
<td>74.4</td>
<td>-69.7561</td>
</tr>
<tr>
<td>2008</td>
<td>1001.2</td>
<td>+5.4861</td>
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<td>-61.0169</td>
<td>392</td>
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</tr>
<tr>
<td>2009</td>
<td>709.5</td>
<td>-25.2473</td>
<td>333</td>
<td>-43.5593</td>
<td>343</td>
<td>39.4309</td>
</tr>
</tbody>
</table>

4.3 Trend of potato production

4.3.1 Trend of annual potato yields in tonnes

The study as shown on Figure 4.4 found that Potato yields have increased between 1999 and 2009 in Oljoro-orok division as shown by the trend line. The increasing annual trend is noticed but the yields have varied over the years. $R^2=0.124$ shows that the strength of the line is weak. Peaks are noticed in 2001, 2003, 2004 and 2007 while dips are noticed in 2000 and 2009. The peaks in 2001 and 2007 are due to favourable rainfall as shown on Figure 4.1 on the annual rainfall trend. The dips in 2000 and 2009 are as a result of the unfavourable rainfall as shown by the dips on Figure 4.1.
4.3.2 Trend of seasonal potato yields in tonnes during the long rain season

From the findings shown in the Figure 4.5, $R^2=0.0461$ shows that the strength of the line is weak. Potato yields have increased in Oljoro-orok between 1999 and 2009 during the long rain season. Peaks are noticed in 2003, 2004 and 2007 while dips are noticed in 2001, 2006 and 2009. The peaks in 2003 and 2007 are as a result of favourable rainfall as shown by the peaks on the Figure 4.2 on seasonal rainfall trend. The dips in 2000 and 2009 are as a result of unfavourable rainfall as shown by the dips on the Figure 4.2 on seasonal rainfall trend. The dip in 2006 was as a result of a dry spell on the upper side of the division as rain was not uniform in the season, it rained more on the lower side than the upper side.
4.3.3 Trend of seasonal potato production in tonnes during the Short rain season

The finding in Figure 4.6 shows that potato yield during the short rain season increased between 1999 and 2009. A peak is noticed in 2007 was as a result of high potato prices towards the end of the short rain season in 2006. More land (3,112 ha) was put under potato in the 2007 long rain period leading to high yield as shown by the peak in Figure 4.6. In 2007 there was delayed cessation of rainfall during the long rain season which resulted to a portion of the long rain season potato yields mixed with the short rain season yields. The short rain season had low rainfall in that year and even though the yields in the upper zone declined due to the dry spell, the yields in the lower zone increased because of the soil water retention capacity.
4.4 Potato Production Variability

Potato production variability was computed using potato variability index. The land under potatoes was not uniform between 1999 and 2009 but ranges between 1400 hectares in 1999 to 3112 hectares in 2007. Annual potato production variability is evident by variations ranging from -33.1369 in 2000 to +60.8892 in 2007 as shown on Table 4.2. Long rain potato production variations ranges from -30.9963 in 2000 to +34.9898 in 2007 as shown on Table 4.2. Short rain potato production variations ranges from -45.2353 in 2000 to +144.0588 in 2007 as shown on Table 4.2.
Table 4.2: Seasonal and annual potato production variability index

<table>
<thead>
<tr>
<th>Year</th>
<th>Annual potato yield in tons</th>
<th>Annual yield variation mean=15474</th>
<th>Seasonal potato yield in tons-long rain season</th>
<th>Seasonal yield variation-long rain season mean=12295</th>
<th>Seasonal potato yield in tons-short rain season</th>
<th>Seasonal yield variation-short rain season mean=3400</th>
</tr>
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<tr>
<td>1999</td>
<td>12600</td>
<td>-18.5731</td>
<td>10332</td>
<td>-15.9658</td>
<td>2268</td>
<td>-33.2941</td>
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<tr>
<td>2000</td>
<td>10346</td>
<td>-33.1369</td>
<td>8484.048</td>
<td>-30.9963</td>
<td>1862.35</td>
<td>-45.2353</td>
</tr>
<tr>
<td>2001</td>
<td>15110</td>
<td>-2.3556</td>
<td>12389.79</td>
<td>-0.7645</td>
<td>2719.71</td>
<td>-20.02941</td>
</tr>
<tr>
<td>2002</td>
<td>13590</td>
<td>-12.1753</td>
<td>13157.31</td>
<td>7.01098</td>
<td>2888.19</td>
<td>-15.0588</td>
</tr>
<tr>
<td>2003</td>
<td>17875</td>
<td>+15.5164</td>
<td>14657.5</td>
<td>19.211</td>
<td>3217.5</td>
<td>-5.3824</td>
</tr>
<tr>
<td>2004</td>
<td>17905</td>
<td>+15.7102</td>
<td>14682.1</td>
<td>19.4144</td>
<td>3222.9</td>
<td>-5.2351</td>
</tr>
<tr>
<td>2005</td>
<td>14654</td>
<td>-5.3008</td>
<td>12016</td>
<td>-2.2692</td>
<td>2637.675</td>
<td>-22.4412</td>
</tr>
<tr>
<td>2006</td>
<td>16443</td>
<td>+6.2621</td>
<td>10962</td>
<td>-1.08174</td>
<td>5481</td>
<td>61.2059</td>
</tr>
<tr>
<td>2007</td>
<td>24896</td>
<td>+60.8892</td>
<td>16597.34</td>
<td>34.9898</td>
<td>8298.65</td>
<td>144.0588</td>
</tr>
<tr>
<td>2008</td>
<td>15295</td>
<td>-1.1568</td>
<td>12541.9</td>
<td>2.008</td>
<td>2753.1</td>
<td>-19.0294</td>
</tr>
</tbody>
</table>

4.5 Comparative trend Analysis

4.5.1 Annual rainfall and potato yields data.
The results in Figure 4.7a and 4.7b show that variation of rainfall causes variations in potato yields in Oljoro-orok division. As shown by Figure 4.7a and 4.7b potato yield and rainfall both increased in Oljoro-orok between 1999 and 2009. The variation on potato yields with variation of rainfall in Oljoro-orok as the study found supports the arguments by KARI (2005) that rainfall determines the type of crop to be grown in different environment as well as the type of agricultural system to be practiced in different parts of the country. The study found that variation and increased Irish potato yields has been caused by variations and increased rainfall in Oljoro-orok division. These findings supports the earlier work by Olaoye (1999) that regular occurrence of drought as a result of erratic rainfall distribution and/or
cessation of rain during the growing season reduce Nigeria’s capability for increased crop production.

**Figure 4.7a: Annual rainfall data trend for years 1999 – 2009**

**Figure 4.7b: Trend of annual Potato yields in tons for the years 1999-2009**

### 4.5.2 Seasonal rainfall and potato yields data during the long rain season.

The results in Figure 4.8a show a decreasing rainfall trend and an increasing potato trend in Figure 4.8b between 1999 and 2009. The potato yield dynamics in the division is as a result of variation of rainfall, different types of soils in both lower and upper zone of the division as well as the potato prices in the previous season. When rainfall is high the lower zone are affected by water logging. When rainfall are low the upper zone of the division namely, Nyairoko and upper Oraitumia location records low yield since the black cotton soils in the area drains very fast.
The lower zone potato yields increase during such a time because the soils there retains water. These argument is supported by Ogola et al. (2011) that there are many factors that affect potato yields, such as lack of clean seed, lack of water and nutrients in the soil, damage from pest and diseases. The peak in the rainfall and potato yields in 2001 and 2007 on Figure 4.8a and 4.8b shows that potato yields increases with increase in rainfall during the long rain season. The dips in 2000 and 2009 in both figures show how potato yields are correlated with rainfall in a growing season.
4.5.3 Seasonal rainfall and potato yields data during the short rain season.

The results in Figure 4.9a and 4.9b show that variation of rainfall causes variations on potato yields in Oljoro-orok division. Both rainfall and potato yields graphs shows an increasing trend between 1999 and 2009 in Oljoro-orok division. According to the Ministry of Agriculture (2007) there were Post-harvest loses in the lower zone due to water logging during the long rain season. In 2007 there was delayed cessation of rainfall during the long rain season which resulted to a portion of the long rain season potato yields mixed with the short rain season yields. The short rain season had low rainfall in that year and even though the yields in the upper zone declined due to the dry spell, the yields in the lower zone increased because of the soil water retention capacity. As explained earlier more land was put under potato due to high potato prices realised in the 2006 short rain season. Fourteen percent (14%) trend on both seasonal rainfall and potato yields indicates that the two lines have equal strength.
4.6 Analysis of rainfall characteristic

4.6.1 Analysis of rainfall characteristics during the long rain season

The results in Table 4.3 shows that onset month have varied, alternating between March, April and May. Five times representing 45.45% the onset was in March; four times representing 36.36% the onset was in April while two times representing 18.18% the onset was in May. The study found that majority of the farmers’ plant potatoes at the beginning of the season with few planting before or after the start of the season that takes between 90 to 120 days. Cessation month has also varied alternating between June, July and August. The numbers of rain days have also varied from 20 in 2005 to 58 in 2007. When farmers are informed on the onset date
they plan on when to prepare their land and acquire the necessary inputs. This finding supports the earlier findings by Adeniyi (2009) that the long term onset time of rainfall is normally used to determine the time of farm clearing and preparation for planting. The peak months ranges from March to July. Potato yields also varied from 8484.048 tons in 2000 to 16597.34 tons in 2007 during the long rain season.

Table 4.3: Summary of rainfall characteristics during the long rain season

<table>
<thead>
<tr>
<th>Year</th>
<th>Peak month of Rainfall</th>
<th>Onset month of rainfall</th>
<th>Cessation month of rainfall</th>
<th>Number of rain days</th>
<th>Potato yield in tons</th>
</tr>
</thead>
<tbody>
<tr>
<td>1999</td>
<td>July</td>
<td>Mar</td>
<td>Aug</td>
<td>23</td>
<td>10332</td>
</tr>
<tr>
<td>2000</td>
<td>June</td>
<td>May</td>
<td>Aug</td>
<td>28</td>
<td>8484.048</td>
</tr>
<tr>
<td>2001</td>
<td>July</td>
<td>Mar</td>
<td>Aug</td>
<td>30</td>
<td>12389.79</td>
</tr>
<tr>
<td>2002</td>
<td>May.</td>
<td>Mar</td>
<td>July</td>
<td>43</td>
<td>13157.31</td>
</tr>
<tr>
<td>2003</td>
<td>July</td>
<td>Apr</td>
<td>Aug</td>
<td>28</td>
<td>14657.5</td>
</tr>
<tr>
<td>2004</td>
<td>July</td>
<td>Apr</td>
<td>Aug</td>
<td>32</td>
<td>14682.1</td>
</tr>
<tr>
<td>2005</td>
<td>May</td>
<td>Apr</td>
<td>July</td>
<td>20</td>
<td>12016</td>
</tr>
<tr>
<td>2006</td>
<td>Mar</td>
<td>Mar</td>
<td>Aug</td>
<td>43</td>
<td>10962</td>
</tr>
<tr>
<td>2007</td>
<td>Apr</td>
<td>Apr</td>
<td>Sep</td>
<td>58</td>
<td>16597.34</td>
</tr>
<tr>
<td>2008</td>
<td>Mar</td>
<td>Mar</td>
<td>June</td>
<td>40</td>
<td>12541.9</td>
</tr>
<tr>
<td>2009</td>
<td>May.</td>
<td>May</td>
<td>July</td>
<td>23</td>
<td>9430</td>
</tr>
</tbody>
</table>

Source: Nyahururu Meteorological Department (rainfall characteristics data) and Nyandarua West District Agriculture Office (potato yield data).

4.6.2 Analysis of rainfall characteristics during the short rain season

The results in Table 4.4 shows that onset month have varied alternating between September and October. Five times representing 45.45% the onset was in September and six times representing 54.55% the onset was in October. Cessation month has also varied alternating between November, December and January. The numbers of rain days have also varied from 31 in 2008 to 61 in 2001. The peak months ranges from October to December. The results found that seasonal change is a challenge in
the division and farmers need to be updated all the time to enable them plant on
time.

Table 4.4: Summary of rainfall characteristics during the short rain season

<table>
<thead>
<tr>
<th>Year</th>
<th>Peak month of Rainfall</th>
<th>Onset month of rainfall</th>
<th>Cessation month of rainfall</th>
<th>Number of rain days</th>
<th>Potato yield in tons</th>
</tr>
</thead>
<tbody>
<tr>
<td>1999</td>
<td>Oct</td>
<td>Oct</td>
<td>Dec</td>
<td>40</td>
<td>2268</td>
</tr>
<tr>
<td>2000</td>
<td>Oct</td>
<td>Sep</td>
<td>Jan</td>
<td>37</td>
<td>1862.35</td>
</tr>
<tr>
<td>2001</td>
<td>Nov</td>
<td>Oct</td>
<td>Jan</td>
<td>61</td>
<td>2719.71</td>
</tr>
<tr>
<td>2002</td>
<td>Dec</td>
<td>Oct</td>
<td>Dec</td>
<td>54</td>
<td>2888.19</td>
</tr>
<tr>
<td>2003</td>
<td>Nov</td>
<td>Oct</td>
<td>Dec</td>
<td>44</td>
<td>3217.5</td>
</tr>
<tr>
<td>2004</td>
<td>Nov</td>
<td>Oct</td>
<td>Dec</td>
<td>41</td>
<td>3222.9</td>
</tr>
<tr>
<td>2005</td>
<td>Nov</td>
<td>Sep</td>
<td>Nov</td>
<td>51</td>
<td>2637.67</td>
</tr>
<tr>
<td>2006</td>
<td>Dec</td>
<td>Sep</td>
<td>Dec</td>
<td>55</td>
<td>5481</td>
</tr>
<tr>
<td>2007</td>
<td>Sep</td>
<td>Sep</td>
<td>Nov</td>
<td>34</td>
<td>8298.6</td>
</tr>
<tr>
<td>2008</td>
<td>Oct</td>
<td>Sep</td>
<td>Nov</td>
<td>31</td>
<td>2753.1</td>
</tr>
<tr>
<td>2009</td>
<td>Dec</td>
<td>Oct</td>
<td>Dec</td>
<td>32</td>
<td>2070</td>
</tr>
</tbody>
</table>

Source: Nyahururu Meteorological Department (rainfall characteristics data) and Nyandarua West District Agriculture Office (potato yield data).

4.7 Correlation of Annual rainfall trend and Annual potato production

The annual rainfall trend and annual potato production as shown on Table 4.5 were
correlated to determine the significance of their relationship. When Pearson’s r is
close to 1, this means that there is a strong relationship between the two variables
and that change in one variable are strongly correlated with changes in the second
variable. When Pearson’s r is close to 0... This means that there is a weak
relationship between the two variables and that change in one variable are not
correlated with changes in the second variable.
Table 4.5: Annual rainfall and Annual potato production trend

<table>
<thead>
<tr>
<th>Year</th>
<th>Annual Rainfall Amount (mm)</th>
<th>Annual potato production(tons)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1999</td>
<td>786.60</td>
<td>12600.00</td>
</tr>
<tr>
<td>2000</td>
<td>617.90</td>
<td>10346.40</td>
</tr>
<tr>
<td>2001</td>
<td>1187.30</td>
<td>15109.50</td>
</tr>
<tr>
<td>2002</td>
<td>961.50</td>
<td>13590.00</td>
</tr>
<tr>
<td>2003</td>
<td>905.90</td>
<td>17875.00</td>
</tr>
<tr>
<td>2004</td>
<td>907.20</td>
<td>17905.00</td>
</tr>
<tr>
<td>2005</td>
<td>890.70</td>
<td>14653.75</td>
</tr>
<tr>
<td>2006</td>
<td>1058.50</td>
<td>16443.00</td>
</tr>
<tr>
<td>2007</td>
<td>1414.10</td>
<td>24896.00</td>
</tr>
<tr>
<td>2008</td>
<td>1001.20</td>
<td>15295.00</td>
</tr>
<tr>
<td>2009</td>
<td>709.50</td>
<td>11500.00</td>
</tr>
</tbody>
</table>

From the findings on Table 4.6, Pearson’s r = 0.839 is close to 1 showing that there is a strong relationship between rainfall amount and potato production. This means that changes in one variable are strongly correlated with changes in the second variable. A positive Pearson’s r means that as one variable increases in value, the second variable also increase in value. Similarly, as one variable decreases in value, the second variable also decreases in value. From the findings the Sig. (2-Tailed) value 0.001 is less than 0.05 meaning that there is a statistically significant correlation between rainfall trend and potato production.
Table 4.6: Correlations

<table>
<thead>
<tr>
<th></th>
<th>Annual rainfall amount(mm)</th>
<th>Potato production(tons)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Annual rainfall amount(mm)</td>
<td>Pearson Correlation: 1</td>
<td>.839**</td>
</tr>
<tr>
<td></td>
<td>Sig. (2-tailed): .839**</td>
<td>.001</td>
</tr>
<tr>
<td></td>
<td>N</td>
<td>11</td>
</tr>
<tr>
<td>Potato production(tons)</td>
<td>Pearson Correlation: .001</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Sig. (2-tailed): .001</td>
<td>11</td>
</tr>
<tr>
<td></td>
<td>N</td>
<td>11</td>
</tr>
</tbody>
</table>

**. Correlation is significant at the 0.01 level (2-tailed).

4.8 Farmers adaptation measures to rainfall variability for potato production

4.8.1 Analysis of the Adaptation measures

From the findings in Table 4.7, crop diversification is most common adaptation measure practised in the division followed by timely planting, off season approach and irrigation. Crop diversification is the most common adaptation measure in Lesirko while irrigation is the least. Timely planting is the most common adaptation measure in Oraimutia and least practised in Nyairoko. Off season approach is the common adaptation measure in Nyairoko location and the least practised in Oraimutia. Irrigation is common in Lesirko location while its least practised in Nyairoko.
Table 4.7: Farmers Adaptation measures

<table>
<thead>
<tr>
<th>Adaptation Measures</th>
<th>LOCATIONS</th>
<th></th>
<th></th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Lesirko</td>
<td>Oraimutia</td>
<td>Nyairoko</td>
<td></td>
</tr>
<tr>
<td>1. Crop diversification</td>
<td>83</td>
<td>42</td>
<td>30</td>
<td>155</td>
</tr>
<tr>
<td>2. Timely planting</td>
<td>38</td>
<td>61</td>
<td>22</td>
<td>121</td>
</tr>
<tr>
<td>3. Off season approach</td>
<td>25</td>
<td>24</td>
<td>50</td>
<td>99</td>
</tr>
<tr>
<td>4. Irrigation</td>
<td>15</td>
<td>10</td>
<td>9</td>
<td>34</td>
</tr>
<tr>
<td>5. Other methods</td>
<td>2</td>
<td>4</td>
<td>6</td>
<td>12</td>
</tr>
<tr>
<td>Total</td>
<td>163</td>
<td>141</td>
<td>117</td>
<td></td>
</tr>
</tbody>
</table>

4.8.2 SWOT Analysis

SWOT Matrix is a strategic planning method used to evaluate the Strengths, Weaknesses/Limitations, Opportunities, and Threats involved in a project. It involves specifying the objective of the project and identifying the internal and external factors that are favourable and unfavourable to achieve that objective. SWOT is an acronym for Strengths, Weaknesses, Opportunities and Threats. Strengths and Weaknesses are considered to be internal factors over which you have some measure of control. Opportunities and Threats are considered to be external factors over which you have essentially no control (Humphrey, 2004). SWOT Analysis is the foundation for evaluating the internal potential and limitations and the likely opportunities and threats from the external environment. In the current study it views all positive and negative factors inside and outside the division that
affect the success of potato production and farmers adaptations to rainfall variability. The use of SWOT analysis in the division helps in predicting the changing trends and including them in the decision-making process of the stakeholders. SWOT analysis was also used in coming up with the recommendation.

**Table 4.8: SWOT matrix**

<table>
<thead>
<tr>
<th><strong>Strengths</strong></th>
<th><strong>Weaknesses</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Farmers are educated and experienced in farming.</td>
<td>Inadequate capital</td>
</tr>
<tr>
<td>Farmers are in their productive age</td>
<td>Water logging in the lower side of the division</td>
</tr>
<tr>
<td>Availability of land and labour</td>
<td>Small land size</td>
</tr>
<tr>
<td>Specialized in potato farming</td>
<td>Soil is not uniform</td>
</tr>
<tr>
<td><strong>Opportunities</strong></td>
<td><strong>Threats</strong></td>
</tr>
<tr>
<td>Presence of KARI in the neighboring Gathanji division and Nyahururu Meteorological Station</td>
<td>Farmers planting according to season and not following seasonal weather forecast</td>
</tr>
<tr>
<td>Presence of Jacob, Gichaka and Ngara Dams whose water flows within and outside the division</td>
<td>Few Agricultural field officers</td>
</tr>
<tr>
<td>Presence of Farmers Training Centre in the neighboring Gatimu division</td>
<td>Mobility of labour as a result of men migration to the urban centers</td>
</tr>
<tr>
<td>Ready market-located near urban centers’ such as Nyahururu, Nakuru, Nyeri and Nairobi</td>
<td>Competition from other potato producing regions leading to price fluctuations.</td>
</tr>
<tr>
<td>Annual farmers field day organized by FTC in the neighboring Gatimu division.</td>
<td>rainfall Variability</td>
</tr>
<tr>
<td>Improved communication and technology which enable faster transfer of information</td>
<td>Seed quality</td>
</tr>
<tr>
<td></td>
<td>Poor market</td>
</tr>
<tr>
<td></td>
<td>poor roads</td>
</tr>
</tbody>
</table>
4.8.3 Analysis of Strengths vs. Weaknesses

The study established that the division has strengths as well as weaknesses facing potato farmers. If well utilized the strengths are able to address the weaknesses hence increasing potato production in the division. According to the Kenya National Bureau of Statistics the Population in the division has continued to increase 65,229 in 1999 to 85825 in 2009. This is likely to put more strain on the already strained resources leading to more land fragmentation and more mouths to feed. As shown in Table 4.9 majority of the respondents, 148 (77.1%) are married, 36 (18.8%) are single while 8 (4.2%) are widowed. High number of married people is an indication that the population is likely to increase in the division and that increased potato production is an immediate measure to assure the division sustainable food security. The high food demand due increase in population in the division is addressed by the farmers specialisation on farming in Oljoro-orok as shown in Table 4.9 where 182 (94.8%) are specialised farmers while 10 (5.2%) are teachers and other professionals. Specialization on farming means that increased production will help farmers to not only feed the growing population but also earn income after selling surplus.

The study found as shown on Figure 4.10 that 161 (83.9%) of the respondents are crop farmers, 137 (71.4%) specialising in potato farming, 10 (5.2%) engaging in maize farming, 14 (7.3%) are vegetable farmers and 31 (16.1%) are dairy farmers. This is an indication that potato farming is the main economic activity in Oljoro-orok Division. The crop is the main source of food and income to the farmers, source of employment to the middlemen, and drivers who transport the yields to the
market and source of revenue to the government. This findings supports the argument by Ogola et al. (2011) and Olanya et al., 2006 that potatoes are important food and cash crops in many parts of Kenya and an important source of income and employment in the rural areas. The decline in potato yield and low potato prices leaves farmers with inadequate capital to buy the necessary inputs in the next season. Inadequate capital is a weakness to potato production because for high yields to be realised heavy investment in terms of resources has to be pumped to potato farming.

Farmers require capital to be able to purchase clean seeds, fertilizers, pesticides, irrigation pumps to be used during the dry spell and other inputs. This is supported by Kuyiah (2007) that cash constraints and small land sizes are the two most important factors that inhibit realization of higher farm incomes and optimal production at farm level. There is need for policies that spur investment in public infrastructure, rural financial markets, private investment, and support institutions to address the problems of high transaction costs to investors, and reduce risks faced by farmers.

Inadequate capital can be addressed by the high literacy levels in the division. Education is important in all human activities. The study found that majority of the respondents as shown on Table 4.9 that 126 (65.6%) were literate (have gone through formal education) while 66 (34.4%) were illiterate (have not gone through formal education). An educated farmer cannot be compared to the one who is uneducated. These educated farmers are in a position to apply for loans and other
credit facilities from the various banks in the County and use their title deeds as security. Education helps farmers in making well informed decision enabling them increase production and adapt to weather uncertainties. This is supported by Uphoff (1996) that formal education broadens the outlook and knowledge of the farmers and thus educated farmers are more receptive to innovations and more likely to adapt to rainfall variability.

A high literacy level in the division is an indication that farmers supplied with the right information have the potential of increasing potato yields in Oljoro-orok hence addressing the challenges of small land size as shown on Figure 4.11. The farmers were more informed on issues of weather changes where majority of the respondents 45% agrees that rainfall variation is the main cause of decreased Irish potato yields as shown on Figure 4.13 and were able to adapt easily through crop diversification during times of rainfall variability where they planted animal feeds such as oat for dairy animals, cabbages and carrots. The farmers also use off season approach to caution themselves from effects of rainfall variability where they plant potato in very small portion of land and leave the rest of the land bare to replenish. This explains why the land under potatoes was not uniform between 1999 and 2009 but ranges between 1400 hectares in 1999 to 3112 hectares in 2007. Other adaptation measures applied include irrigation and timely planting
The study found that the division has enough human resource needed to improved potato production. Results as in Table 4.10 show that majority of the respondents 159 (82.8%) were between 23-65 years of age while 33 (17.2%) were above 65 years. This is an indication that the farmers are in their productive years. The farmers have the capacity to apply any rainfall adaptation measures that requires their labour which is available. The high population of farmers who are in their working years is a resource that when well utilized will address the challenges of small land size through intensive farming. The findings support the earlier argument

Table 4.9: Respondents Background information

<table>
<thead>
<tr>
<th>Marital status</th>
<th>Frequency</th>
<th>Percent</th>
<th>Cumulative Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Married</td>
<td>148</td>
<td>77.1</td>
<td>77.1</td>
</tr>
<tr>
<td>Single</td>
<td>36</td>
<td>18.8</td>
<td>95.8</td>
</tr>
<tr>
<td>Widowed</td>
<td>8</td>
<td>4.2</td>
<td>100.0</td>
</tr>
<tr>
<td>TOTAL</td>
<td>192</td>
<td>100.0</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Occupation</th>
<th>Frequency</th>
<th>Percent</th>
<th>Cumulative Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Farmer</td>
<td>182</td>
<td>94.8</td>
<td>94.8</td>
</tr>
<tr>
<td>Teacher</td>
<td>10</td>
<td>5.2</td>
<td>100.0</td>
</tr>
<tr>
<td>TOTAL</td>
<td>192</td>
<td>100.0</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Education level</th>
<th>Frequency</th>
<th>Percent</th>
<th>Cumulative Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Literate (have formal Education)</td>
<td>126</td>
<td>65.6</td>
<td>65.6</td>
</tr>
<tr>
<td>Illiterate (have no formal Education)</td>
<td>66</td>
<td>34.4</td>
<td>100.0</td>
</tr>
<tr>
<td>TOTAL</td>
<td>100.0</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
that availability of family labour is vital to farm production especially in terms of the amount of land that can be brought under cultivation. Although from the earlier study labour alone is not a sufficient factor. Availability and access to land and other productive resources is critical (Moock, 1973).

Table 4.10: Respondents Background information Cont..

<table>
<thead>
<tr>
<th>Age group</th>
<th>Frequency</th>
<th>Percent</th>
<th>Cumulative Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>23- 65 years</td>
<td>159</td>
<td>82.8</td>
<td>82.8</td>
</tr>
<tr>
<td>Above 65 years</td>
<td>33</td>
<td>17.2</td>
<td>100.0</td>
</tr>
<tr>
<td>TOTAL</td>
<td>192</td>
<td>100.0</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Gender</th>
<th>Frequency</th>
<th>Percent</th>
<th>Cumulative Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>58</td>
<td>30.2</td>
<td>30.2</td>
</tr>
<tr>
<td>Female</td>
<td>134</td>
<td>69.8</td>
<td>100.0</td>
</tr>
<tr>
<td>TOTAL</td>
<td>192</td>
<td>100.0</td>
<td></td>
</tr>
</tbody>
</table>
Figure 4.10: Type of activities carried out by the land user

Availability of land is important to a meaningful farming in Oljoro-orok division. Majority of the farmers own the land as shown on Table 4.11 where 168 (87.5%) of the respondents own the land, 22 (11.5%) had leased the land while 2 (1%) own the land communally. This means that more farmers don’t incur extra charges on leasing the land which would reduce their profit margin. Farmers who are planting on leased land incur more losses in times of crop failure due to rainfall variability and are less receptive to adaptation measures because their stay on the land is not determined. They only use short time approaches such as crop diversification where they plant other crops like vegetables that can mature fast on the bases of their lease agreement.
and cannot afford long term measures such as off season approaches because their stay in the land is limited.

**Table 4.11: Type of land ownership**

<table>
<thead>
<tr>
<th></th>
<th>Frequency</th>
<th>Percent</th>
<th>Cumulative Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Communal</td>
<td>2</td>
<td>1.0</td>
<td>1.0</td>
</tr>
<tr>
<td>Lease</td>
<td>22</td>
<td>11.5</td>
<td>12.5</td>
</tr>
<tr>
<td>Owner</td>
<td>168</td>
<td>87.5</td>
<td>100.0</td>
</tr>
<tr>
<td>Total</td>
<td>192</td>
<td>100.0</td>
<td></td>
</tr>
</tbody>
</table>

Experience enable farmer to learn new trends of weather patterns, pest and diseases and the best time of planting to realise profit because of the market forces. The results found in Table 4.12, show that majority of the respondents 163 (84.9%) have grown potatoes for over 5 years, 20 (10.4%) have grown potatoes for between 1-5 years while 9 (4.7%) have grown potatoes for less than one year. Inexperienced farmers face many challenges while increased farming experience enables the farmer gain more confidence and increased productivity. The experience of the farmers has enabled them understand the dynamics of water logging in the lower side of the division and the effect of inadequate rainfall in the upper parts of the division due to un uniform soils. Experience will enhance farmers’ adaptation to rainfall variability for increased potato production in the division.
Table 4.12: The Duration the respondents have grown Irish potatoes in Oljoro-orok

<table>
<thead>
<tr>
<th>Duration</th>
<th>Frequency</th>
<th>Percent</th>
<th>Cumulative Percent</th>
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<tr>
<td>Less than 1 year</td>
<td>9</td>
<td>4.7</td>
<td>4.7</td>
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<tr>
<td>1- 5 years</td>
<td>20</td>
<td>10.4</td>
<td>15.1</td>
</tr>
<tr>
<td>Over 5 years</td>
<td>163</td>
<td>84.9</td>
<td>100.0</td>
</tr>
<tr>
<td>Total</td>
<td>192</td>
<td>100.0</td>
<td></td>
</tr>
</tbody>
</table>

Although land is available in Oljoro-orok division majority of the people own small sizes of land thus the need to use the land to the maximum so that potato yields can be enough to cater for their needs. As shown in Figure 4.11, 20.8% of the respondents own between 1-2 acres of land, 20.8% own between 2-3 acres, 19.27% own between 4-5 acres, 18.23% own between 3-4 acres, 7.8% own 0-1 acres while 13% own above 5 acres of land. Farmers in the division need to maximally invest on the available land to increase production because land for expansion is limited in the division. This finding is supported by Ogola et al. (2011) that small land size is an indication that intensive farming is the only option to enhance production.

The study found that there is limited land for expansion in the division which leave farmers with only an option to invest on maximising potato yields. The results are supported by McCalla (1994) and Young (1999) that new land that can be put under
agriculture is limited, contrary to the last three decades, where the bulk of food production in Sub-Saharan Africa came from expansion of agricultural lands. The opportunities to increase crop yields under rain-fed agriculture strongly rest on focusing our attention on maximizing yield per unit of water applied.

Figure 4.11 Distribution of the land holding

4.8.4 Analysis of Opportunities vs. Threats
The study established that the division has Opportunities as well as threats facing potato farmers. If well utilized the opportunities are able to address the threats hence increasing potato production in the division. Seed quality is a threat to increased potato production in Oljoro-orok division. Planting clean seeds helps in preventing the passing of negative traits from one season to the next. As shown on Figure 4.12, 71.4% of the respondents’ plant indigenous potato species (immediately harvested
from fellow farmers and not certified ones from Kenya Agricultural research institute). The challenge of seed quality can be addressed by the presence Kenya Agricultural Research Institute in the neighbouring Gathanji division where farmers can buy quality seeds and also seek advice on the suitability of seeds in the division.

The study found that, twenty five percent (25%) of the respondents plant their crops according to traditions and don’t rely on the seasonal weather forecasts from Kenya Meteorological Department. The respondents plant according to a tradition that is planting during a certain time when they have been planting as the start of the season each year. Three point six percent (3.6%) of the respondents plant using their own spacing and not as advised by agriculture field officers. They use the knowledge of planting passed from one generation to the next. Planting according to tradition exposes farmers to great losses when weather changes. From the findings farmers don’t plant according to seasonal weather forecasts from Kenya Meteorological Department and this leads to decreased potato yields or total crop failure in case of changes on the onset of rainfall. Agriculture field officers should educate the farmers on the importance of seasonal weather forecasts and also update them from time to time. The presence of Nyahururu Meteorological Station will help farmers receive seasonal weather forecast on time for them to decide when to plant based on the onset dates from Meteorological department. The Agricultural field officers should liaise with Nyahururu Meteorological and advice farmers on the onset and cessation of rainfall so that they don’t incur losses that can arise in case of rainfall variations. The presence of Jacob, Gichaka and Ngara Dams whose water flows within and outside the division when well utilised will help solve the challenges of rainfall
variability. Potato farmers in Oljoro-orok needs to embraces modern technology and follow the seasonal weather forecast from the meteorological department. Improved communication and technology will enable faster transfer of information and reach many farmers within a short period of time. The time of planting is very important for it gives the plant an opportunity to mature before the dry spell.

**Figure 4.12: The indigenous methods of farming employed in the farms according to the respondents**
Table 4.13 Scientific methods of farming employed by farmers

<table>
<thead>
<tr>
<th>Method</th>
<th>Frequency</th>
<th>Percent</th>
<th>Cumulative Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Planting of hybrid seeds from KARI</td>
<td>77</td>
<td>40.1</td>
<td>40.1</td>
</tr>
<tr>
<td>Planting according to seasonal weather focus from KMD</td>
<td>38</td>
<td>19.8</td>
<td>59.9</td>
</tr>
<tr>
<td>Planting using standards spacing as advised by field officers</td>
<td>77</td>
<td>40.1</td>
<td>100.0</td>
</tr>
<tr>
<td>Total</td>
<td>192</td>
<td>100.0</td>
<td></td>
</tr>
</tbody>
</table>

As discussed above majority of the farmers plant the very harvested seeds as opposed to clean highbred seeds. Table 4.13, shows that only 77 (40.1%) of farmers plant hybrid clean seeds from Kenya Agricultural Research institute while the rest plant the very harvested seeds in the next season. Very few farmers 38 (19.8%) plant according to seasonal weather forecast from the Kenya Meteorological Department while the rest plant according to tradition. 77 (40.1%) of the respondents plant potatoes using standard spacing as advised by Agricultural field officers while the rest plant according to their own spacing knowledge. Farmers should frequently visit KARI and seek information on the types of seeds and the scientific methods of farming.
The findings support the arguments by Muga (2010) that all channels of communication should be utilised to ensure that the farmers receive the vital information on time to enable them plan well. This will reduce rainfall variability impact on Oljoro-orok farmers by distributing seasonal weather forecasts (based on short-term and long-term forecasts) so that they can make more informed farming decisions and adapt to the changing weather conditions.

According to the respondents; rainfall variation and lack of clean seeds are the main challenges to potato farming. As shown in Figure 4.11, majority of the respondents 45% agrees that rainfall variation is the main cause of decreased Irish potato yields in Oljoro-orok division. 33% lack of clean seeds, 8% soil degeneration, 6% diseases and high cost of farm inputs while 2% see inadequate field officers as the cause of decreased potato yields. Rainfall is the only source of water to the Irish potatoes in the division and therefore means that a variation of rainfall leads to variations of potato yields. The study found out that the division is endowed with resources which when well utilised will be a great opportunity to potato farmers in Oljoro-orok division. The division has three major dams namely; Jacob, Gichaka and Ngara. The water in these water bodies can be utilised for irrigation during the dry spell during the times of unfavourable rainfall (below 700mm) in the upper sides of the division.

Lack of clean seeds which has been found to be the second major threat to potato farming cause low yields since farmers do not get certified varieties which can do
best in their areas and which can be stored for a long time after harvesting to cushion them against poor selling prices. As a result, only 40.1% as shown on Table 4.10 use certified potato seeds while 71.4% as shown in Figure 4.13 plant the very same potatoes they harvest. Planting of the immediate harvested seeds spread diseases in the farm and all other negative traits which lead to low yields. The study found that clean seeds are not available to farmers and when available they are not affordable because majority of the farmers have insufficient capital and relay on potato farming as a source of their livelihoods. Other challenges that have been identified include; inadequate field officers which denies farmers vital information on the best seeds to be planted on which soils, in which quantities and where. The number of farmers is not proportional to the number of field officers in the division. Presence of farmers training centre is an avenue for training more officers to address the shortage. Potato diseases such as potato blight have also led to pre-harvest and post harvest losses in the division and at time increasing the cost of inputs because of the cost of pesticides that the farms spray the land hence reducing the profit margins.

The findings supports the earlier work by Olanya et al. (2004) that late blight and bacterial wilt were regarded by farmers in Nyandarua as the most common diseases. Field officers are supposed to inform farmers on the scientific methods of farming, the best pesticides to use, the best types of seeds to plant and the right spacing to plant the potato seeds in the division. When the officers are few, farmers lack the much needed advice on the scientific methods of farming which leads to low yields.
Though labour is available there is a threat of male migration to urban areas as shown on Table 4.10 where majority of the respondents 134 (69.8%) were women while 58 (30.2%) were male. The migration of men was as results of variations in potato production which is their main source of income due to rainfall variability forcing them to seek an alternative source of income through employment. This findings supports argument by Peacock, et al. (2004) that agriculture is becoming predominantly a female sector as a consequence of faster male out-migration. There are tasks that women cannot do alone without the help of men and therefore combined efforts between men and women will help improve potato farming. Potato farming needs to be made more attractive to help reduce migration of men who do so to look for better opportunities.
The annual farmers field day organized by Farmers Training College in the neighbouring Gatimu division is an important event that should be utilized to educate farmers on the best farming practices. The field day is an opportunity where farmers should learn the emerging types of seeds, methods of planting and new technologies. All farmers should be attending the event because the products displayed there are mostly meant to benefit the division hence making farming attractive and reduce migrations.

The study also found competition and poor market as threats to potato marketing. Competition from other potato producing regions has continued to exploit Oljoro-orok farmers through package of bags with an extended woven nets targeting Wakulima market in Nairobi. The most commonly accepted unit of marketing potatoes is the sisal bag of roughly 100kgs. However major urban centres like Nairobi demand an ‘extended bag’ (with sisal net extension woven onto each bag which weigh from 110-150 kg (MoA, 2007) as shown on Plate 4.1. The extended bag has been used to deny growers their rightful share of the revenue as the bag is sold at similar prices to the ordinary bag and no reference to weight is made. However the division is strategically located near major urban centres such as Nyahururu, Nakuru, and Nyeri.

This towns offer ready market and therefore it is an opportunity since the market is ready for increased yields and the towns don’t demand the extended bags. Although the division is strategically located inaccessibility still remains the major challenge. Most of the feeder roads are normally impassable during the rainy season and it
becomes very difficult for farmers to sell their produce. The County government of Nyandarua should improve rehabilitate the feeder roads to enable farmers transport their produce to the market throughout the year.

Plate 4.1 Potato bags with sisal net extension woven onto each bag which weighs from 110-150 kg.

Source: Author (2012).
CHAPTER FIVE

SUMMARY OF FINDINGS, CONCLUSIONS AND RECOMMENDATIONS.

5.0 Introduction

This chapter presents a summary of the research findings based on the specific objectives, conclusions from the findings and recommendations drawn from the conclusions. The study sought to determine the relationships of rainfall variability and potato production in Oljoro-orok division, Nyandarua County.

5.1 Summary of findings

The study set out to achieve the following objectives:

I. To assess seasonal and annual rainfall and potato production trend and variability between 1999 and 2009 in Oljoro-orok division.

II. To analyse seasonal and annual rainfall characteristics and correlate them with potato production in the division.

III. To evaluate the farmers adaptive capacity for potato production in Oljoro-orok division.

In the first objective, the study found that annual rainfall has increased between 1999 and 2009. The short rain season data contributes a lot to the increasing trend on the annual rainfall since rainfall trend was decreasing during the long rain season and increasing during the short rain season. Peaks are noticed in 2001 and 2007
while dips are noticed in 2000 and 2009 on the annual trend. Rainfall variability in both annual and seasonal trends was significant. Rainfall variability is significant in both seasonal and annual trends ranging from -34.898 in 2000 to +48.9897 in 2007 on the annual trend, -61.0170 in 2008 to +105.7627 in 2007 during the long rain season and -69.7561 in 2007 to +61.7886 in 2006 during the short rain season. Potato yield trend was also increasing between 1999 and 2009, on both annual and seasonal trends. Potato yield variability is evident by variations ranging from -33.1369 in 2000 to +60.8892 in 2007 on the annual trend, -30.9963 in 2000 to +34.9898 in 2007 during the long rain season and -45.2353 in 2000 to +144.0588 in 2007 during the short rain season.

On the second objective, the study found that there is significant relationship between annual and seasonal rainfall characteristics and annual and seasonal potato production in Oljoro-orok Division. Potato yield variability is as a result of rainfall variability.

Finally on the third objective, the study found that farmers have adapted to rainfall variability through 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 unfavourable rainfall. The farmers also use off season approach where they leave a portion of the land bare to replenish during unfavourable rainfall seasons. This has led to fluctuations of the land under potatoes between 1999 and 2009 ranging between 1400 hectares in 1999 to 3112 hectares in 2007.
5.2 Conclusions

The main objective of the study was to find out the effects of rainfall variability on Irish potato production in Oljoro-orok Division. The study found rainfall amounts have increased over the years between 1999 and 2009 in Oljoro-orok Division. The study also found that there is significant relationship between rainfall characteristics and potato production in Oljoro-orok division. Rainfall characteristics and potato production have varied over the years between 1999 and 2009. Variability of rainfall leads to variation of potato yield, as rainfall is the main source of water for potato growth. From the study $r = 0.839$ is close to 1 showing that there is a strong relationship between rainfall amount and potato production. The upper zone of the division has a well drained soil while the lower zone has soils with high water retention capacity hence able to retain water during the dry spell. There has been a shift on the onset and cessation of rainfall. The onset alternates from March to May during the long rain season and September and November during the short rain season. The cessation alternates from June to August during the long rain season and November and January during the short rain season.

Potato farmers in Oljoro-orok division face several challenges. Rainfall variation, lack of clean seeds, soil degeneration, diseases, high cost of farm inputs and inadequate field officers are found to be the major challenges potato production is facing. Clean seeds are either not available or when available they are very
expensive and farmers can’t afford to buy them. Agricultural field officers are few as compared to farmers and this has denied the farmers an opportunity to receive vital scientific knowledge necessary to increase their production. The study reveals that most farmers in Oljoro-orok division plant according to traditions and not according to seasonal weather forecast from Kenya Meteorological Department. Planting according to tradition leaves farmers vulnerable in case of unforeseen change of onset. From the findings the named challenges; rainfall variations, lack of clean seeds, inadequate field officers and pest and diseases if solved the crop still remains economical to plant in Oljoro-orok division. Irish potato matures within a short period of time and this enables the farmers to plant two seasons in a year unlike maize which take one year to mature in Oljoro-orok Division. The study has 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 unfavourable 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 unfavourable rainfall. The farmers off season approach has led to fluctuations of the land under potatoes between 1999 and 2009 ranging between 1400 hectares in 1999 to 3112 hectares in 2007.
5.3 Recommendations

5.3.1 Recommendation for policy Action
Soil and water management practices should be enhanced to reduce loss of moisture from the soil and increase soil water retention capacity during dry spell in the upper sides of the division. In the lower side of the division more trenches should be dug to reduce cases of water logging during heavy rain seasons. This water should be drained into earth dams hence more earth dams should be dug so that they can store water which together with the existing dams such as Gichaka, Jacob and Ngara should be utilised for irrigation on the upper side of the division during the unfavourable rainfall seasons in Oljoro-orok division.

Farmers should be encouraged to enhance crop diversification to caution them from rainfall variability. They should practise crop intensification to increase potato production. Training of farmers on importance of timely planting should be intensified to utilise the available rains at their different stages of growth such as flowering and maturity.

The farmers’ field day organized by Farmers Training College should be organized more frequently to enable more farmers to attend and advise them on the appropriate adaptation.
5.3.2 Recommendation for further research
Research is required on selection of potato varieties that will do well with limited rainfall in Oljoro-orok Division.

Research is also required on the effects of rainfall variations on the marketing of potatoes in Oljoro-orok Division.
REFERENCE


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Metz, B., Davidson, R., Boseh, P., Dave, R., Meyer, L. (2007). Climate change mitigation contribution of working group III to the fourth assessment report of the intergovernmental panel on climate change. Cambridge, UK.


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Obare, G., Nyagaka, D., Nguyo, W. And Mwakubo, S. (2010); Are Kenyan smallholders allocatively efficient? Evidence from Irish potato producers in Nyandarua North district, Egerton University found, Egerton.


RMI (Royal Meteorological Institute) (2009); Klimatologisch overzicht van hetjaar 2008. Royal Meteorological Institute of Belgium, Brussels.


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APPENDICIES

APPENDIX A1; Questionnaires used in this study

I am undertaking a research on the weather variability, analysis for improved potato yields in Oljoro-orok division. To accomplish this task, I do hereby seek your assistance by answering the questions that follow. The information will only be used to devise adaptation measures to mitigate the problem in the area. Your cooperation is highly appreciated.

Respondents number......................................

District......................................Location..........................................Sub Location.................

*Please tick where appropriate*  □

Part I; Farmers Details

House hold information

<table>
<thead>
<tr>
<th>Age..........</th>
<th>Sex..........................</th>
</tr>
</thead>
<tbody>
<tr>
<td>Marital status.........................Occupation..........................</td>
<td></td>
</tr>
<tr>
<td>Level of Education..........................................................</td>
<td></td>
</tr>
</tbody>
</table>
**Land Tenure and Use**

1) Size of the land holding? Less than 2 acres ☐ 2-5 acres ☐ Over 5 acres ☐

2) Type of ownership  Communal ☐ Lease ☐ owner ☐

3) Type of activities carried out by the land user......

   Crop farming ☐ specify the types of crop grown..............................

   Animal rearing ☐ specify the types of animals kept. ............................

4) For how long have you been growing Irish potatoes?  Less than 1 yr ☐ 1-5 yrs ☐ Over 5yrs ☐

**Part II - Farmers Adaptation to rainfall variability**

5) What do you think are challenges facing potato production in Oljoro-orok?

   Rainfall variability ☐ Lack of clean seeds ☐ Soil degeneration ☐
   Diseases ☐ Inadequate field officers ☐
   High cost of Inputs ☐
   Others............................................................................................................

6) If your in question 5 is rainfall variability what are some of the adaptation measures that you apply in your farm to cope with it?

7) Which are the indigenous methods of farming you are employing in your farm?

   Planting the harvested seeds from the farm and neighbouring farms ☐
   Using traditional methods of weather focus instead of relying on seasonal
focus from Kenya meteorological department

Planting using my own spacing and not as advised by field officer

8) Which are the Scientific methods of farming are you employing in your farm?

Planting of certified seeds from KARI

Planting according to seasonal Weather focus from KMD

Planting using standard spacing as advised by field officers

Practising crop rotation
## APPENDIX A<sub>2</sub>: Annual Rainfall data (1999 – 2009)

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<th>Year</th>
<th>Jan</th>
<th>Feb</th>
<th>Mar</th>
<th>Apr</th>
<th>May</th>
<th>Jun</th>
<th>July</th>
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<td>2003</td>
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<td>121</td>
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<td>201.2</td>
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<td>76.3</td>
<td>160.2</td>
<td>28.5</td>
<td>54</td>
<td>104</td>
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<td>41.2</td>
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<td>90</td>
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<td>121</td>
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<td>57.7</td>
<td>138.3</td>
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**Source:** Nyahururu Meteorological Department (2011)

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**Source:** Nyandarua West District Agriculture Office (2011)