Assessing the Socio-economic Vulnerability of Smallholder Farmers to Climate Variability in Rwanda: Case Study of Rice Farmers in Bugesera District

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Supervisor: Dr. Gaspard RWANYIZIRI

Huye, June 2016

Declaration

I hereby declare that this research report is the result of my own original work. It is being submitted for the degree of Masters of Science in Geo-Information for Environmental and Sustainable Development. I also declare that it has not been submitted for a higher degree to any other institution or university.

Jean Damascene MUNYESHYAKA

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Name and Signature of the Candidate Date

Dr. Gaspard RWANYIZIRI

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Name and Signature of Supervisor Date

Dedication

‘I dedicate this thesis to my lovely family and friends. Love you all so much!’

Acknowledgment

First and foremost, I conceive and extend my sincere gratitude to my supervisor Dr. Gaspard Rwanyiziri for being a fantastic principal supervisor throughout my study at the University of Rwanda. He has provided me with interesting comments on this thesis. Without his encouragement, timely suggestions and proper guidance, it was impossible for me to complete this thesis. I express my sincere gratitude for everything I have learnt from him, and for everything he has done for me.

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Abstract

Rwanda has experienced the climate variability with regard to frequency, intensity and persistence of extremes such as heavy rainfall which resulted serious floods, prolonged drought and climatologic parameters. Changing in temperature and precipitations due to climate variability has affected poor people particularly; smallholder farmers who rely mostly on rain feed agriculture for their livelihood. The purpose of this study was to assess the socio-economic vulnerability of smallholder farmers to climate variability effects in Rwanda by focussing on rice farmers in Bugesera District. The data used in this study were collected by using different methods and techniques including review of existing published and unpublished reports, analysis of meteorology data, field observation, household questionnaire and interviews. For data analysis, SPSS and Microsoft Excel software were used.

The research findings revealed that the rice production in Bugesera District has been affected by fluctuation of rainfall and increased of temperature which tremendously affects socio-economically the livelihoods of smallholder farmers. In this framework, the research findings revealed that 90% of rice farmers observed the reduction of rice production due to climate variability, leading to the problem of food crisis, while 85% reported difficulties in paying school fees for their children as well as recruiting new staff in farming related activities. In adaptation to these climate variability effects, rice farmers have adopted different adaptation measures to cope with the impact of drought and floods such as investing in irrigation mechanisms (52%), use of drought resistant rice varieties (25%), use of pesticides and insecticides (9%) and investing in drainage system. In addition to rice farmers efforts, public and government supports for irrigation infrastructure should be increased including the construction of water reservoir to collect water for irrigation purpose during dry season and affordable agriculture inputs and pesticides to increase soil nutrients and combat with pests should be taken into account by the government for better sustainable solution to climate variability effects.

Key Words: *Climate Variability, Socio-economic Vulnerability, Rice Farmers, Drought, Floods, Adaptation Strategies*

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List of Abbreviations and Acronyms

CGIS	Center for Geographical Information System
COGIRIRU	Coopérative Girubumwe Rizicole de Ruvubu
CORI	Coopérative de Riziculture
EICV	Integrated Household Living Conditions Survey (Enquête Intégrale sur les Conditions de Vie des ménages)
FAO	Food and Agriculture Organization
GHGs	Green House Gases
GIS	Geographical Information System
GISS	Goddard Institute for Space Studies
GPS	Global Positioning System
GoR	Government of Rwanda
IFAD	International Fund for Agricultural Development
IPCC	Intergovernmental Panel on Climate Change
MINAGRI	Ministry of Agriculture and Animal Resource
MINITERE	Ministry of Lands, Environment, Forestry, Water and Mines
NASA	National Aeronautics and Space Administration
NISR	National Institute Statistics of Rwanda
REMA	Rwanda Environment Management Authority
RMA	Rwanda Meteorological Agency
SPSS	Statistical Package for Social Sciences
SSA	Sub-Saharan Africa
UNDP	United Nations Development Project
UNEP	United Nations Environment Program
UNFCCC	United Nations Framework Convention on Climate Change
WMO	World Meteorological Organization

CHAPTER ONE: INTRODUCTION

1.1. Background Information

Climate variability is expected to lead to expansion of marginal lands (IPCC, 2007). Rising temperatures and increasing rainfall variability, notably drought are also expected to exacerbate declining outputs, further compromising economic growth and stability, employment levels, food insecurity, demand for other goods and poverty reduction (Muller et *al*., 2011).

Scientists, economists and policy makers have stated that the entire globe is facing a real and serious long-term threat from climate variability (Buckland, 1997; Kinuthia, 1997; Hansen *et al.*, 2007 and Matarira *et al.,* 1995). Projections predict that, by the end of the 21st century, climate change will have had substantial impact on agricultural production and, hence, on the scope for reducing poverty (Slater *et al*., 2007). Climate variability can have different effects on livelihoods ranging from adverse to beneficial effects. Changes are most crucial for livelihoods highly dependent on agricultural production with as main inputs precipitation and temperature (Duns, 2011).

Poter & Somenov (2005) pointed out that agriculture is always vulnerable to unfavorable weather events and climate conditions. Variations and changes in temperature and precipitation have increased the risks in crop productions. Despite technological advances such as improved crop varieties and irrigation systems, weather and climate are important factors, which play a significant role to agricultural productivity (Basak, 2010). Mutsvangwa (2009) argues that the unimpeded growth of greenhouse gas emissions leading to the raising in the earth's temperature, combined with growth in the world's population, threatens food and livelihood security for large numbers of people especially in developing countries.

Sheehy et *al*. (2005) argues that an increase of CO_2 concentration in the atmosphere has a positive effect on crop biomass production, but its net effect on rice yield depends on possible yield reductions associated with increasing temperature. For every 75 ppm increase in CO_2 concentration rice yields will increase by 0.5 t ha-1, but yield will decrease by 0.6 t ha-1 for every 1 °C increase in temperature. Matthews et *al*. (1997) pointed out that, the simulated yield reduction from a 1ºC rise in mean daily temperature varied from 5-7% for major crops, including

rice. The yield reduction was mostly associated with decrease in sink formation, shortening of growth duration and increase in maintenance respiration (Matthews and Wassmann, 2003).

Mutsvangwa (2009) pointed out that Latin America and South East Asia also have large numbers of poor people, who are vulnerable to the impacts of climate variability. Projections predict that developing nations will be affected the most because of their geographical and climatic conditions, their high dependence on agriculture and natural resources driven activities, and limited capacity to adapt to the changing climate. In fact, the capacity to adapt is undermined by the limited availability of social, economic, political and technical resources available to these countries and communities (Erikson et *al*, 2008).

Moreover, Africa is considered very vulnerable to climate change because of widespread poverty (Eriksen *et al.,* 2008). Population pressure depends on marginal land and combining with poor farming practices to facilitate coping and adaptation strategy, have also contributed to high levels of vulnerability to the variability of climate. Action Aid (2008) stated that changing rainfall patterns and higher temperatures have forced farmers in Malawi to shorten the growing season and switch to more expensive hybrid crops. Frequent droughts and floods are eroding assets and leaving people more vulnerable to disaster. According to the same organization, it is widely understood that floods and droughts destroy and erode assets that are the very means for adaptation. When their frequency and intensity increases, farmers are left with no time to recover from previous impacts through either asset accumulation or acquiring the skills and knowledge necessary for adapting to future climate changes. Consequently, farmers are being subjected to continuous hunger and deeper cycles of poverty and vulnerability.

Since the1980s, the Eastern part of Africa is experiencing the brunt of global climate change that hints the seasons become more unpredictable and distribution of rainfall unreliable, making it difficult for farmers to plan for their farming and marketing activities. Therefore, the effects are felt by the poor people particularly, smallholder farmers who rely mostly on agriculture for their livelihood. Rainfall has increasingly become less reliable in each passing year, resulting in seasonal planting and harvesting disruptions, leading to huge economic losses to farmers (Cuts, 2013).In the last 30 years, Rwanda has also experienced the climate variability with regard to frequency (number of occurrences), intensity and persistence of extremes such as heavy

rainfall, waves of heat, drought and climatologic parameters such as El Niño and Nina. To understand the current droughts in Rwanda, it is better to glance at the phenomena in the history. The table bellow shows those episodes in different periods of years.

Table 1: **Period of El Nino / La Nina Episode and Famine in Rwanda (1900-2006)**

Period	**Episode**	**Catastrophe**	**Consequence**	**Affected Region**
1900/1903	El Nino episode	-	"*Kimwaramara* "Famine	South (Huye)
1916/1918	La Nina episode	-	"*Rumanura*" famine	Generalized
1924/1925	La Nina episode	-	Famine	Various regions
1944/1945	La Nina episode	Drought	"Ruzagayura" Famine	Generalized
1963	Eli Nino episode	Diluvian rain	"*Rwagakoca*" famine	Generalized
1982/1983	El Nino episode	Drought, strong heat	Low agriculture production	Generalized
1986/1987	El Nino episode	Strong heat	-	-
1990	La Nina Episode	-	Famine	Various regions
1991/1992	El Nino episode	Drought	-	East
1997/1998	El Nino episode	Drought, high heat	-	-
1999/2000	La Nina episode	Drought, high heat	Famine	East of the country especially Bugesera
2005/2006	La Nina episode	High heat and prolonged drought	Famine, water sources draying, tendency of desertification	Generalized; East and South mostly affected

Source: MINITERE & UNEP (2006).

As noted by UNEP (2011) droughts in Rwanda are mainly triggered by a prolonged dry season or a delay in the onset of the rainy season. Periodic drought incidence over the past decade, between

1998 and 2000, and annually from 2002 to 2005, has caused a serious deterioration in food security. Droughts have caused crop failures and severe food deficits, threatening the most vulnerable farmers with malnutrition and famine (UNDP, REMA and UNEP, 2007). Bugesera District experienced severe droughts in 1999 & 2000 and in 2007 (REMA, 2009). The livelihoods of people in Bugesera are relying on agriculture. So long dry spells have great impacts on their livelihoods and wellbeing.

Crop failure during the 2000 drought meant that the entire region had to depend on external food supplies to pull their live back from the razor's edge. The length and intensity of land degradation have also weakened the lands' resilience. When combined with overgrazing and poor cultivation practices, drought has led to deterioration in pasture and arable land to the point where they have been abandoned. Variability of climatic conditions has been associated with declining food crop production due to low moisture content. Uwamariya (2013) stated that climate variability has an impact on the wage earning in the area. In 2006, about 350 ha of wetlands located around Akanyaru River were flooded and could not be cultivated for the following two years. REMA (2009) declared that Cassava, the main food and income-generating crop is now a rare commodity; and the production of beans has also been negatively affected by the low soil moisture.

1.2. Problem Statement

Rwanda has been faced with unusual irregularities in climate patterns including extreme temperatures, variability in rainfall frequencies and intensity over the last 30 years (RMS, 2004). The analysis of rainfall trends showed that rainy seasons have tended to become shorter with higher intensity. The events such as droughts and floods associated with heavy rainfall and extreme temperatures have been reported ever more in Eastern and Northern parts of Rwanda respectively (Rwanyiziri & Rugema, 2013). Climate-related shocks like drought and flooding are becoming more regular. The poor are particularly vulnerable to these shocks. The Eastern and Southeastern regions (Nyagatare, Ngoma and Bugesera) are most affected by prolonged drought while the Northern and Western regions (Musanze, Gicumbi and Rubavu,) experience abundant rainfall that usually causes erosion, flooding and landslides (REMA, 2009). These phenomena result in the decrease of agricultural production that sometimes leads to widespread famines and poverty, of which most cases occurred in the years 2000 and 2004 in Bugesera District and a certain number of other regions of the country. Valley-bottoms crops often suffer decreased production and are sometimes destroyed

by flooding in marshlands. Due to this reason many areas within these regions are continually faced and affected by food shortage whenever climatic variability effects get worse (MINITERE & UNEP, 2006).

The purpose of this study is to analyze at what extent smallholder rice farmers in wetland zones of Bugesera District are vulnerable to climate variability. This eventually helps in proposing some adaptation strategies that contain sound measures to reduce the climate risks and the socio-economic vulnerability of farmers under different rice production systems.

1.3. Objectives

1.3.1. General Objective

The general objective of this research is to assess the socio-economic vulnerability of smallholder farmers to climate variability effects in Rwanda by focussing on rice farmers in Bugesera District from 1985 to 2014.

1.3.2. Specific Objectives

1) To analyse rainfall and temperature patterns and their effects on rice production in Bugesera District;

2) To investigate at what extent rice farmers are socio-economically vulnerable to the effects of climate variability in the study area;

3) To propose possible adaptation strategies in addressing the socio-economic vulnerability of rice farmers to climate variability effects.

1.4. Hypotheses

1) There is variability in rainfall and temperature patterns in the study area.

2) Rice farmers of Bugesera District are socio-economically vulnerable to the effects of climate variability.

3) There are difficulties in adaption measures to cope with climate variability effects in the study area

1.5. Research Questions

The study is guided by the following main research question: to what extend rice farmers are socio-economically vulnerable to climate variability in Bugesera District?' This question is further guided by the following sub-questions:

a) What is the trend in terms of rainfall and temperature patterns in the study area?
b) What are major effects of climate variability on rice production in Bugesera District?
c) How do rice farmers are socio-economically vulnerable to climate variability impacts?

d) What are major adaptation strategies to cope with climate variability effects?

1.6. Scope of the Study

In the past, two key studies on some aspects of climate variability and change related matters have been carried out in different parts of Bugesera District. In 2013, for example, Gaspard Rwanyiziri and John Rugema published a scientific paper on the effects of climate change on food security by focusing on wetland rice farmers. However, they didn't analyze at what extend rice farmers are socio-economic vulnerable taking into account their local livelihoods. In 2015, Christine Uzayisenga successfully defended an MSc thesis on the effects of climate change on agriculture production and vulnerability to food insecurity among smallholder farmers in general. However, she didn't focus on rice farmers. The originality of this study is to focus on the assessment of the socio-economic vulnerability to climate variability by smallholder rice farmers over 30 years means from 1985 to 2014 by proposing some adaptation strategies.

CHAPTER TWO: LITERATURE REVIEW

This chapter is introducing an overview of what is known to date, the causes and impacts of climate variability, Variability of temperature and rainfall in Rwanda. The chapter also provides the analytical framework of the impacts of climate variability on rice production.

2.1. Definition of Key Concepts

2.1.1 Climate

Climate in a narrow sense is usually defined as the "average weather" or more rigorously as the statistical description in terms of the mean and variability of relevant quantities over a period of time ranging from months to thousands or millions of years. The classical period is 30 years, as defined by the World Meteorological Organization (WMO). These relevant quantities are most often surface variables such as temperature, precipitation, and wind. Climate in a wider sense is the state, including a statistical description, of the climate system (REMA, 2010).

2.1.2 Climate Variability

Climate variability refers to variations in the mean state and other statistics (such as standard deviations, the occurrence of extremes, etc.) of the climate on all temporal and spatial scales beyond that of individual weather events. Variability may be due to natural internal processes within the climate system (internal variability), or to variations in natural or anthropogenic external forcing (external variability) and can be additionally caused by El Niño and La Niña events from the oceans. Simply climate variability refers to the way climate fluctuates yearly above or below a long-term average value.

2.1.3 Climate Change

Statistically tests Climate change refers to a change in the state of the climate that can be identified by changes in the mean and/or the variability of its properties, and that persists for an extended period, typically decades or longer. Climate change may be due to natural internal processes or external forcing such as modulations of the solar cycles, volcanic eruptions, and persistent anthropogenic changes in the composition of the atmosphere or in land use.

Note that the Framework Convention on Climate Change (UNFCCC), in its Article 1, defines climate change as: "a change of climate which is attributed directly or indirectly to human activity that alters the composition of the global atmosphere and which is in addition to natural climate variability observed over comparable time periods".

The UNFCCC thus makes a distinction between climate change attributable to human activities altering the atmospheric composition, and climate variability attributable to natural causes (IPCC, 2014). Briefly climate change refers to the long-term continuous change (increase or decrease) to average weather conditions or the range of weather.

2.1.4 Drought and Flood as Extreme Climate Events

2.1.4.1 Drought

Is a deficiency in precipitation over an extended period, usually a season or more, resulting in a water shortage causing adverse impacts on vegetation, animals, and/or people. It is a normal, recurrent feature of climate that occurs in virtually all climate zones, from very wet to very dry. Drought is a temporary aberration from normal climatic conditions, thus it can vary significantly from one region to another (NDMC, 2008).

2.1.4.2 Flooding

It is a natural event or occurrence where a piece of land (or area) that is usually dry land, suddenly get submerged under water. Some floods can occur suddenly and recede quickly and others take days or even months to build and discharge. Floods are more widespread and bring more losses to economic sectors, such as industry and agriculture.

2.1.5 Vulnerability

The IPCC definition characterizes vulnerability (to climate variability and change) as a function of a system’s exposure and sensitivity to climatic stimuli and its capacity to adapt to their (adverse) effects (IPCC, 2007), which corresponds to outcome (or end-point) vulnerability, but it does not provide a clear definition of these attributes or the relationship between them. Figure 2

illustrates the relationship between key terms employed in climate change impact, vulnerability, and adaptation assessment.

Note that the term 'vulnerability' refers to outcome vulnerability and the term 'impacts' refers to potential biophysical impacts. Simply terms, vulnerability describes the exposure to hazard and shocks (Action Aid International, 2005).

ISDR (2004) define the mathematical relation as follows

Risk= Hazard x Vulnerability

Hence, **Vulnerability** $= \frac{\text{Risk}}{\text{Hazard}}$ On other hand, Whitehead et al. (2005) incorporate the notion of coping capacity in the relationship, as follow

Vulnerability$= \frac{\text{Exposure x Susceptibility}}{\text{Copping capacity}}$ Where copping capacity refer to the use of available resources and capacities to face the adverse impacts of hazards.

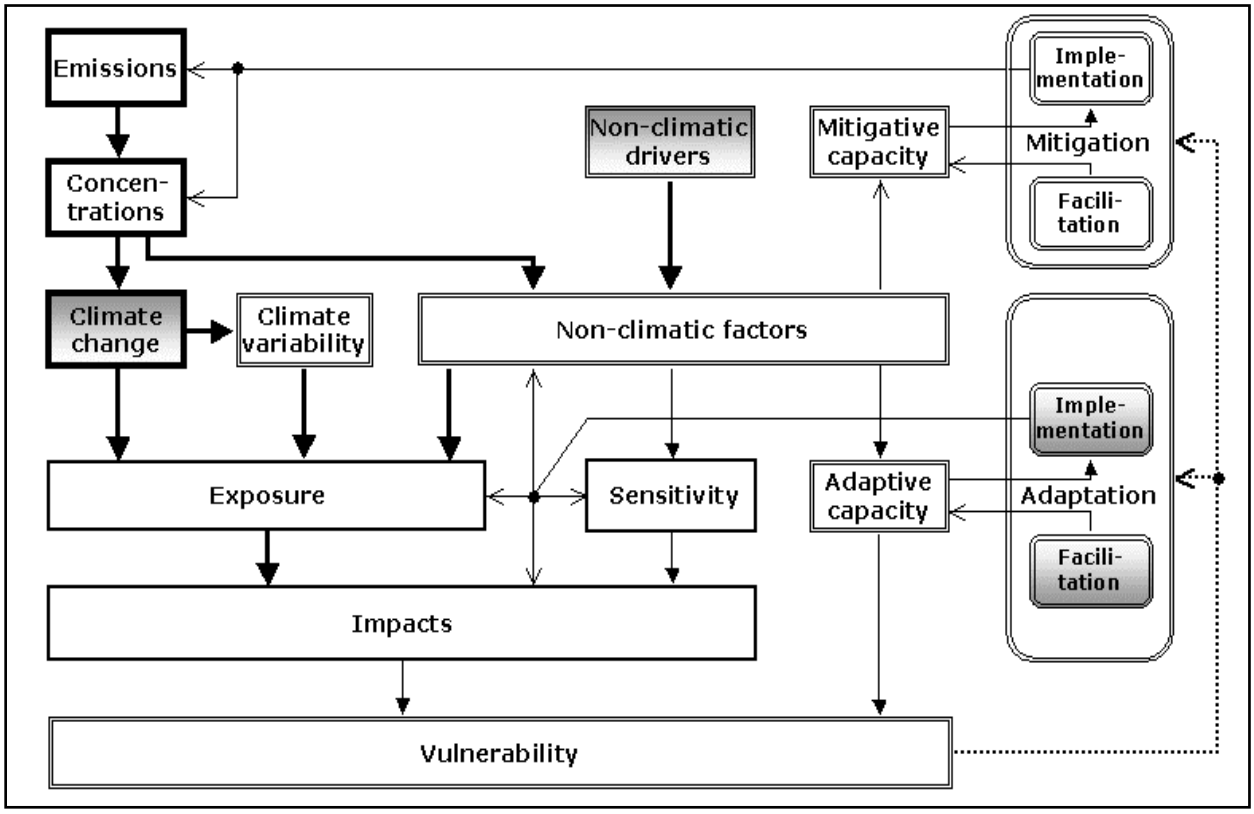

Figure 1: **Relationship between Climate Variability Impact, Vulnerability, and Adaptation Assessment (**Füssel and Klein, 2006**)**

2.1.6 Socio-economic Vulnerability

Socio-economic Vulnerability is an aggregate measure of human welfare that integrates environmental, social, economic and political exposure to a range of harmful perturbations. Cutter et *al*. (2003) argued that Social-economic vulnerability describes drivers of the population that influence the capacity of the community to prepare for, respond to, and recover from hazards and disasters.

Social vulnerability interacts with natural processes and the built environment to redistribute the risks and impacts of natural hazards and in this way creates the social burdens of hazards.

2.1.7 Adaptation and Mitigation Strategies

According to IPCC (2001), adaptation refers to "adjustments in ecological, social or economic systems in response to actual or expected stimuli and their effects or impacts. This term refers to changes in processes, practices and structures to moderate potential damages or to benefit from opportunities associated with climate variability". In this framework, according to the same author, adaptation involves adjustments to decrease the vulnerability of communities, regions, and nations to climate variability and in promoting sustainable development.

Mitigation activities which seek to reduce the human effects on global warming by reducing the quantity of greenhouse gases released to the atmosphere. IPCC (2001) argued that mitigation can be defined as an anthropogenic intervention to reduce the source or enhance the sinks of greenhouse gases.

2.2. Climate Variability in Rwanda

Estimates from the Fourth IPCC Assessment Report indicate that average surface temperature in Africa have registered increases in the range of 0.2 to 2.0 °C during the period 1970 – 2004. The same estimates suggest that over the next century, annual temperatures in Rwanda may be 1.0° C to 2.0° C higher during the next century i.e. 2010-2100.

The observations and analysis from existing data shows that over the last 30 years, some parts of Rwanda have experienced unusual irregularities in climate patterns including variability in rainfall frequencies and intensity, persistence of extremes like heavy rainfall in the northern parts

and drought in the eastern and southern parts (REMA, 2009). The 1997 floods and prolonged drought of 2000 associated with El Nino and La Nina are some of the extreme climate change events that Rwanda has suffered signifying climate change (MINITERE, 2006).

The eastern region of the country has been experiencing rainfall deficits over the last decades. Observations between 1961 and 2005 showed that the period between 1991 and 2000 has been the driest since 1961. These observations showed a marked deficit in 1992, 1993, 1996, 1999 and 2000 with rainfall excesses in 1998 and 2001 (MINITERE, 2006).

REMA (2010) pointed out that vulnerability of climate variability in Rwanda has already been experienced in the areas of agriculture and food security; renewable energy; frequency of natural disasters and epidemics, among others.

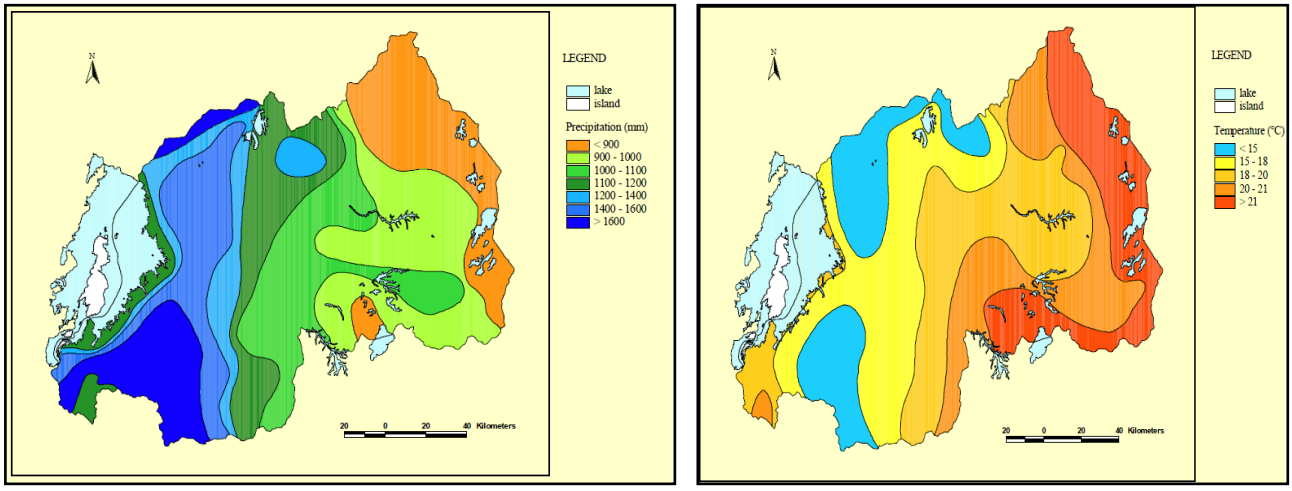

Figure 2: **Rainfall and Temperature Distribution in Rwanda** (Verdoodt and Van Ranst, 2003)

2.2.1 Variability of Temperature

Rwanda has a moderate tropical climate due to its high altitude. Average temperature turns around 20°C with no significant differences. Nowadays there are some irregularities in rainfall. Wind is generally low about 1 to 3 m/s (MINILENA, 2005). In high regions of Congo-Nile crater, temperatures vary between 15° and 17°C with abundant rains. The volcanoes region has lower temperatures reaching less than 0°C in some areas. In intermediary altitude zones, temperatures vary between 19 to 29°C with an average rainfall of about 1000 mm/year.

Rainfalls are less regular which sometimes lead to dry periods. In low altitude zones (East and South East), temperatures are higher and the highest can reach 30°C in February and July-August. Maximum absolute temperature of 32.8°C was registered at Karama–Plateau station in South East at 4th September 1980 (MINILENA, 2005).

2.2.2 Variability of Rainfall

UNEP (2011) reported that rainfall is more variable. Rainfall averages 1,200 mm annually and ranges from 2,000 mm in the western and north-western highlands to 600 mm in the eastern savanna, where rainfall events are more erratic with frequent droughts. Rwanyiziri & Rugema (2013) indicated that the highest rainfall was observed in the year 1998, 2001, 2010 and the lowest in 1992, 2000 and 2008. REMA (2009) pointed out that Eastern and Southeastern regions are more affected by prolonged droughts while the northern and western regions experience abundant rainfall that at times cause erosion, flooding and landslides.

However, rainfall defines Rwanda's seasons. The climate is divided into two rainy and two dry seasons almost throughout the country: long rainy season (February to May with 48 percent of annual rainfall); long dry season (June to mid-September); short rainy season (mid-September to December with 30 percent of annual rainfall); and short dry season from (January to February with 22 percent of annual rainfall) (UNEP, 2011).

In additional, seasonal rainfall distribution in Rwanda is influenced by three key factors: (i) its equatorial and continental location; (ii) the southwest monsoon, which brings most of the rain and global phenomena, particularly the El Niño Southern Oscillation; and (iii) the moderating role of the Great Lakes (Victoria, Tanganyika and Kivu).

2.3. Climate Variability and Rice Production

Climate variability leads to increased temperatures, changing rainfall patterns and amounts, and a higher frequency and intensity of extreme climate events such as floods, cyclone, droughts, and heat wave (IPCC, 2007). Agriculture is the most important sector and it is set to be hit the hardest by climate change in Sub-Saharan Africa (Comba and Muchapondwa 2012). Koyama (2005) reported that high temperatures would cause a marked decrease in world rice production.

In addition the study conducted by FAO demonstrated that the production and distribution of rice food in different part of the world might be affected greatly by global climate change.

FAO (2010) reported that in SSA, agriculture remains the main contributor to socio-economic development of many countries. Temperature increases and erratic rainfall patterns affect crop agriculture most directly and adversely (Almaraz et *al.*, 2008).

Temperature and rainfall change have a diverse impact on crop area, production level and yield. Karn (2014) found out that a 1°C rise in day-time maximum temperature during the ripening phase of rice increases harvest by 27 kg. Ha-1 and the analyses also suggest that productivity declines when the daytime maximum temperature goes beyond 29.9°C. Since the average maximum temperature is already higher than this threshold, rice yield will likely diminish with any further increases in maximum temperature.

Rainfall appears to have a strong negative effect on yield if it occurs when rice plants are in the nursery stage

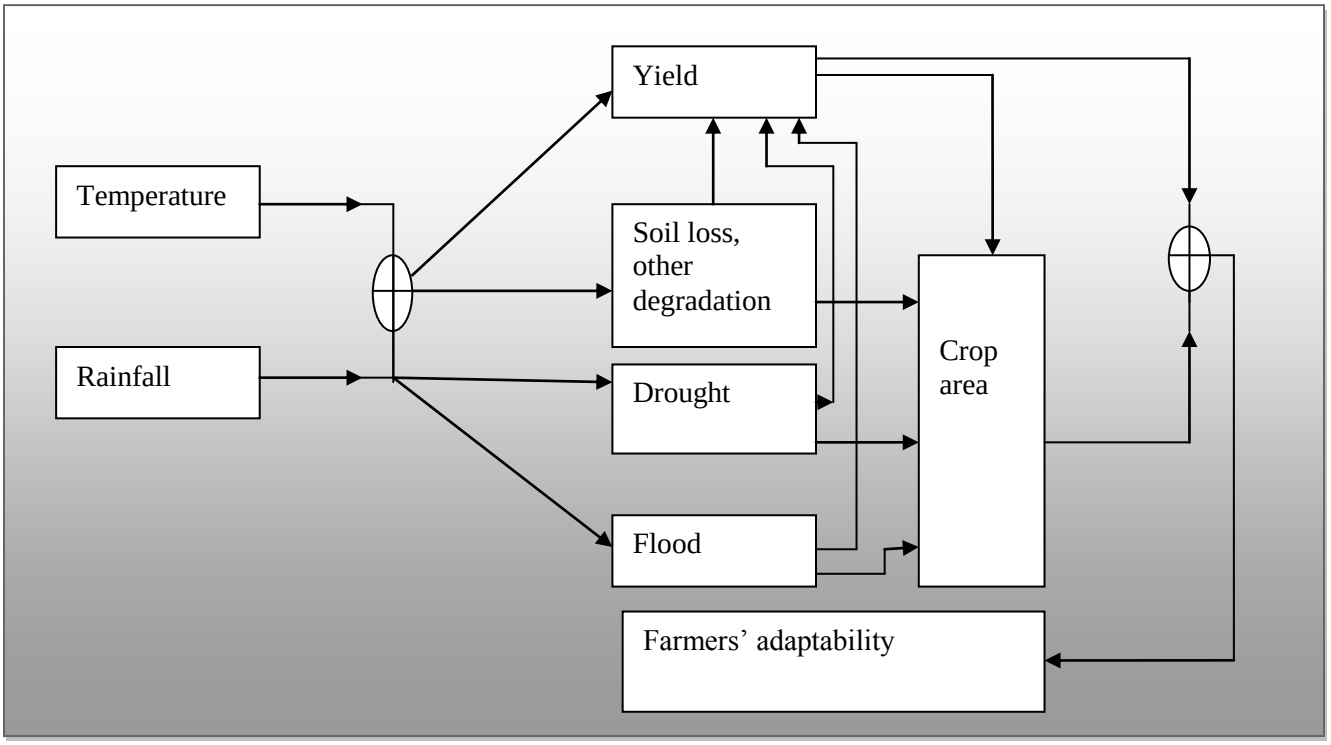

Figure 3: **Conceptual Framework of Climate Variability Impacts on Rice Production** (Abdur, 2012)

CHAPTER THREE: MATERIALS AND METHODS

This chapter presents the methodology used for the study. It describes the study area and after gives the details on different techniques and methods used to collect and analyze the data.

3.1. Study Area Description

This research was conducted in the lowlands of Rwanda in Bugesera region that has experienced long periods of drought and low levels of rainfall. Bugesera District is one of the seven districts that make up Rwanda's Eastern Province. It has a total surface area of 1,288.4 km^2. It has fifteen sectors (Gashora, Juru, Kamabuye, Ntarama, Mareba, Mayange, Musenyi, Mwogo, Ngeruka, Nyamata, Nyarugenge, Rilima, Ruhuha, Rweru and Shyara) in total. Bugesera District boarders with the Districts of Nyarugenge and Kicukiro of the City of Kigali in the North; the District of Rwamagana in the Northeast; the District of Kamonyi in the Northwest; the District of Ngoma in East; the Districts of Ruhango and the District of Nyanza in the west and the Republic of Burundi in the South (Bugesera District, 2013).

Bugesera's relief has a succession of undulating hills, dry valleys and some marshes due to tectonic collapse and the district is equally rich in marshlands alongside rivers; they cover an estimated area of 6,100 ha and are exploited at an average of 46.3% (Bugesera District, 2006). It is characterized with a mixture of plateaus with an altitude varying between 1,100m and 1,780m and most prominent of these hills are: Mont Shyara (1,772 m), Mont Juru (1667 m), Mont Maranyundo (1,614 m), and Mont Mwendo (1575m)(Bugesera District, 2013). The highest rainfall ever recorded was 1300 mm in 1969 but annual precipitation ranges between 700-900 mm. The mean atmospheric temperature varies but is usually between 21º C and 29º C (UNEP, 2011).

Socio-economically, Bugesera district is predominantly a rural area and the main occupation of the population is subsistence agriculture. There are two main agricultural seasons (A and B). Season A begins from September to February and the season B starts mid-January and finishes in May. However, during the long dry season (June-August) there is Season C where farmers exploit marshlands when they are drained (Kabirigi M. et al., 2015).

According to the Third Integrated Household Living Conditions Survey (EICV3), Bugesera district is at the 17th position in the country to have a percentage of Households involved in agriculture and livestock activities. Crop farming and livestock rearing are the district's economy's backbones where by 77.8% of the population depend on agriculture against 72% for national average (NISR, 2012). According to same source, 72.3% of the households have less than 1ha of land to be cultivated. Mixed farming is the most common farming system and households rely on family labor. Farming is usually done using hoes and machetes. Intercropping, crop rotation and use of some soil and water conservation techniques are typically practiced. The main food crops grown in Bugesera are sorghum, maize, groundnuts, cassava, soybean, sweet potatoes, beans, and rice. Rice is grown on approximately 560 ha of wetlands in former Ngenda District (UNEP, UNDP and REMA, 2007).

As indicated in previous paragraphs, this study was conducted in Bugesera District. Two wetlands namely Ruvubu and Nyaburiba lying in three sectors of Bugesera District considered and the respondents to this study were smallholder rice farmers (grouped into two cooperatives namely CORI Nyaburiba and COOGIRIRU) living in Shyara, Nyarugenge and Ruhuha sectors.

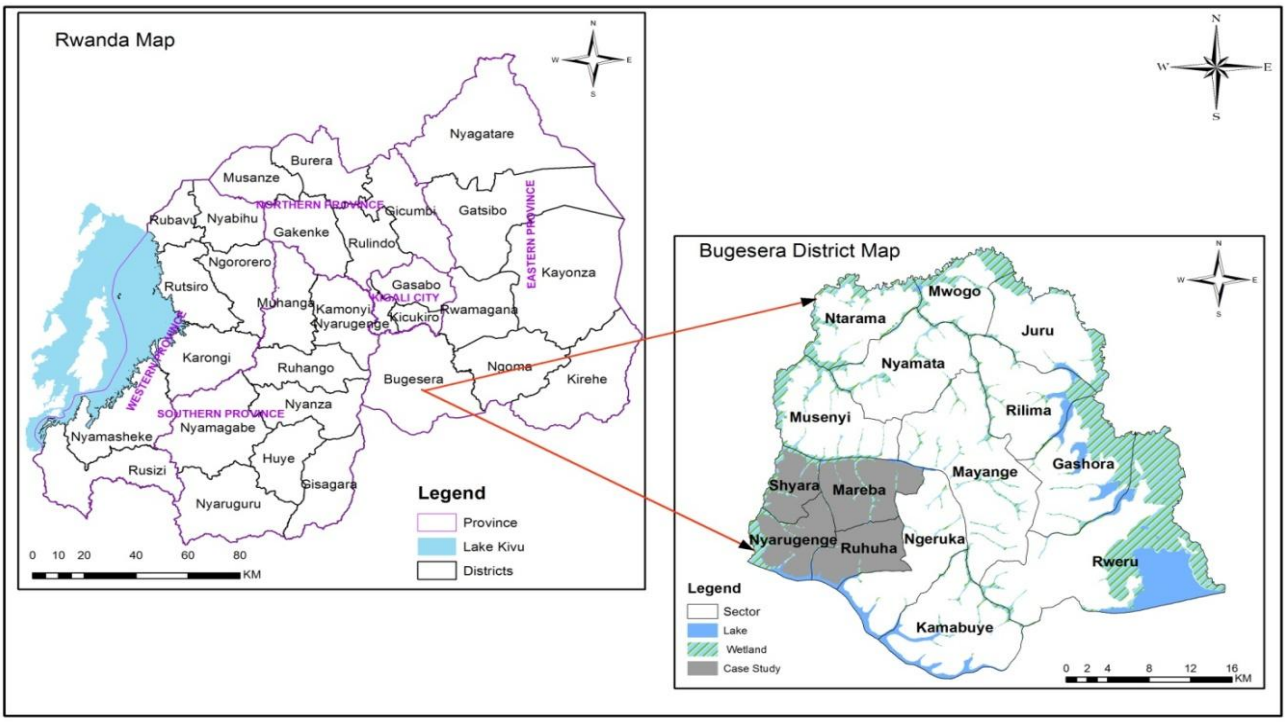

Figure 4: **Map of the Study Area** (MINITRACO/CGIS, 2001)

3.2. Data Collection Techniques

Data for this study was obtained from both primary and secondary data sources.

3.2.1. Secondary Data Sources

Secondary data were collected through literature review of various published books, reports, scientific papers, international and Government institution from libraries and internet. This was intended to thoroughly understand the socio-economic vulnerability of rice farmers, climate change and their impact in general. In addition the literature review was made in order to link rice production, food security and climate variability.

3.2.2 Primary Data Sources

To achieve the research objectives a multi-method approach of collecting data was used. These methods and techniques include field observations, household questionnaire survey and interviews.

3. 2. 2.1. Field Observation

This technique was used in assessing geo-physically some existing rice farming practices in the study. Some pictures on rice farming practices were taken by using a digital camera.

3.2.2.2. Household Questionnaire Survey

a) Population of the Study

The study population was the local farmers engaged in small-scale rice production grouped into two cooperatives namely COOGIRIRU and CORI Nyaburiba. They were targeted because farmers practice different crop production systems in the study area and are being adversely affected by changes in climate in the rice crop farming.

b) Sample Size

Among 800 Rice farmers grouped into two cooperatives were composed the population of the study. However, only 100 respondents randomly selected from the population study serve as the sample, 50 from COGIRIBU and 50 rice farmers from CORI Nyaburiba.

Sample size of 100 farmers was taken based on time availability. Gender balance was considered while sampling, since women are basically much more involved in horticulture in Rwanda.

c) Administration of the Questionnaire

The questionnaire containing only close-ended questions was used. Hired enumerators met rice farmers in their farming parcels because it was not easily to select rice farmers in their respective homes from three sectors. Heads of households were requested to answer to all questions. During that assignment, face-to-face interviews were privileged.

3.2.3. Interviews

This technique was used to know the point of view from key decision-makers about the level of socio-economic vulnerability of rice farmers to climate variability effects. It is in this line that key informants were mainly presidents of cooperatives; environmental officer at district level; and agronomists at sector levels. Their views, observations, and experiences with regard to the research problem were sought. Face to face interviews with the above-mentioned key informants were conducted by using a short interview guide.

3.3. Data Analysis

Several methods of data analysis were used. Including statistical analysis of socio-economic data (primary/secondary) by using SPSS version 16.0 and the output statistical results from SPSS were exported in excel sheet for production of graphs and tables which was used to present results of the findings. SPSS 16.0 was also used in analyzing climate data and rice production of over the past 10 years beginning from 2005 to 2014. In addition to analyze the trends of temperature and rainfall Patterns and their effect on local rice farmers, 30 years beginning 1985 to 2014 were considered. Data from Kigali International Airport Meteorological Station was used in this research due to its nearest position to the study area and this station locates in low land and has accurate data. Finally, the statistical analysis was used to determine the measure of central tendency like mean and dispersion such as Standard Deviation (SD) and Coefficient of Variation (CV).

CHAPTER FOUR: RESULTS AND DISCUSSION

This chapter presents the results after analyzing the findings from the data collected by means of questionnaire and interview guide questions with the key informant. The results have been discussed based on the literature review from different published materials on socio-economic vulnerability of smallholder farmers to climate variability.

4.1. Analysis of Temperature and Rainfall Patterns and their Effect on Rice Production

4.1.1. Trends in Temperature and Precipitation Patterns

As the study area has no weather station which have full data of 30 years, one meteorological station (Kigali Airport) closer to the study area was selected to know the variability of rainfall and temperature patterns.

Measuring climatic variability involves evaluating the gap between the achievements of the climate variable (rainfall or temperature) and its equilibrium value. This equilibrium value refers to the existence of a permanent state or trend (Badolo & Somlanare, 2014). Generally, we measure climatic variability by the standard deviation or the average deviation in absolute value of the distribution of a variable, relative to its mean or to its long-term trend. The standard deviation weights the extreme events more strongly than the average deviation. Other indicators of climatic variability may be the variation coefficient.

Climate variability has been assessed by using various simple statistical methods. The table 2 illustrates three variability of climate commonly used such as average annual maximum temperature, average annual minimum temperature and average annual total rainfall. These variables are calculated based on monthly data from Kigali Airport Station. Three time periods (three decades) are considered to examine the variability over time.

From the table 2 the mean of both average annual maximum temperature and average annual minimum temperature have both increased over three periods of 10 years each.
Standard deviation of average maximum temperature has increased gradually while relative variability measured by standard deviation on average minimum temperature reset constant over

three periods. Absolute variability measured by coefficient of variation of both average maximum temperature and average minimum temperature has progressively increased over three periods. Mean of annual average total rainfall of three considered periods of Kigali Airport station have been decreased. By comparing all these fluctuation of three periods it is clear that there is enough evidence of a changing of climate at Kigali Airport station over the last 30 years.

Table 2: **Climate Variability in Kigali Airport Station between 1985 and 2014**

Climate Variability	Statistical Tools	1985-1994	1995-2004	2005-2014
Average Annual Maximum Temperature (°C)	Mean	26.4	27.3	27.4
	Standard Deviation	0.9	1	1
	Coefficient of Variation (%)	3.3	3.7	3.8
Average Annual Minimum Temperature (°C)	Mean	15.5	15.9	16.4
	Standard Deviation	0.5	0.5	0.5
	Coefficient of Variation (%)	3.2	3.3	2.6
Average Annual Total Rainfall (mm)	Mean	85.5	83.3	82.7
	Standard Deviation	61.9	56.4	60.8
	Coefficient of Variation (%)	76.3	70.9	70.1

Source: RMA (2014)

By analyzing the variability in mean annual maximum temperature and rainfall from 1985 up to 2014 at Kigali Airport, we found a high increase in 2005 with 28.2^{o} C and this led to high heat and prolonged drought in Bugesera District; consequently, famine, drying of water sources and tendency of desertification happened in the region; and the lowest temperature was observed in 1989 with 25.8^{o}C. Year with the highest annual rainfall was observed in 2013, which recorded an

amount of 1,386.6 mm with a corresponding highest mean value of 115.6 mm. Generally the annual mean maximum temperature indicates an increasing trend and the annual mean rainfall is in the decreasing trend. Due to the variability of climate, local farmers are more vulnerable to the impact of the change.

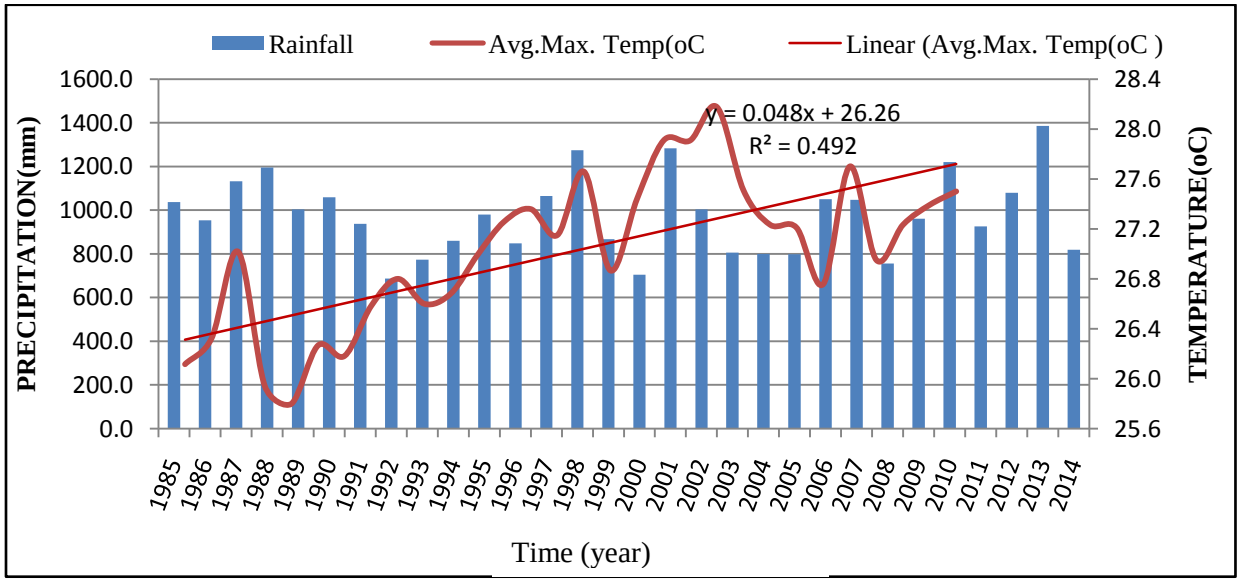

Figure 5: **Relationship between Temperature and Rainfall at Kigali Airport Station** (RMA, 2014).

Maximum temperature increased sharply (R^2=0.4933) while annual rainfall had been decreasing (R^2=0.0014) in last 30 years. These results confirmed findings from others studies carried out in `Bugesera District (Rwanyiziri & Rugema, 2013 & Uzayisenga, 2013) that there has an increase of temperature and declining trend of rainfall. The increasing of temperature and decrease of rainfall has affected different crops of local farmers in Bugesera District including rice farmers.

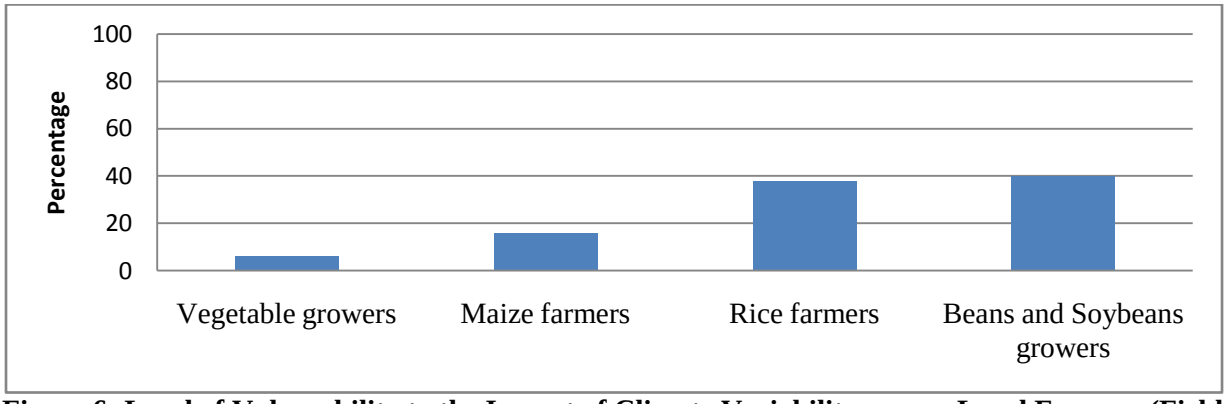

Figure 6: Level of Vulnerability to the Impact of Climate Variability among Local Farmers (Field Survey, 2016)

The results above (Figure 6) indicated that 40 % of respondents reported that beans and soybeans growers are the most vulnerable to climate variability in Bugesera District due to the prolonged drought while 38% ranked rice growers at second place. According to the same survey, maize farmers are less vulnerable (16%) as maize crop resists to climate variability in the region.

4.1.2. Perceptions of Rice Farmers about Climate Variability

Firstly rice farmers should perceive that there is climate variability in order to take necessary adaptive strategies (Abdur, 2012). Hassan and Nhemachena (2008) argued that the awareness of climate problems and the potential benefits of taking action is an important measure for adoption of agricultural technologies. The questions related to climate variability were asked to rice farmers in order to understand their' views about the notion of climate variability.

The study revealed that the majority of rice farmers (84%) have heard about climate variability. Only 16% of them were reported that have never heard about climate variability. This gives a clear image that rice farmers in Bugesera District are well clued-up about climate variability. These findings reflect positively to climate variability adaptation measures. This cannot be achieved without getting rice farmers who are aware of local climate variability. Thulani and Keith (2013) argued that one of the greatest limitations to climate variability adaptation in Africa is about lack of climate variability information. Indeed, it is well known that "*if you do not know where you are coming from, you cannot know where you are going"*.

The awareness of Bugesera rice farmers on climate variability goes with the age group. The study revealed that around 73 % of the respondents were aged between 31-55 years. Respondents with 56 years and above formed 14 percent of the total number of 100 respondents. Having a high percentage of respondents aged between 31-55 was much appropriate because the information sought required one to have a historical understanding of the state of climate variability in the local area at least for three last decades. The source of information on climate variability within smallholder rice farmers are represented in the figure 7.

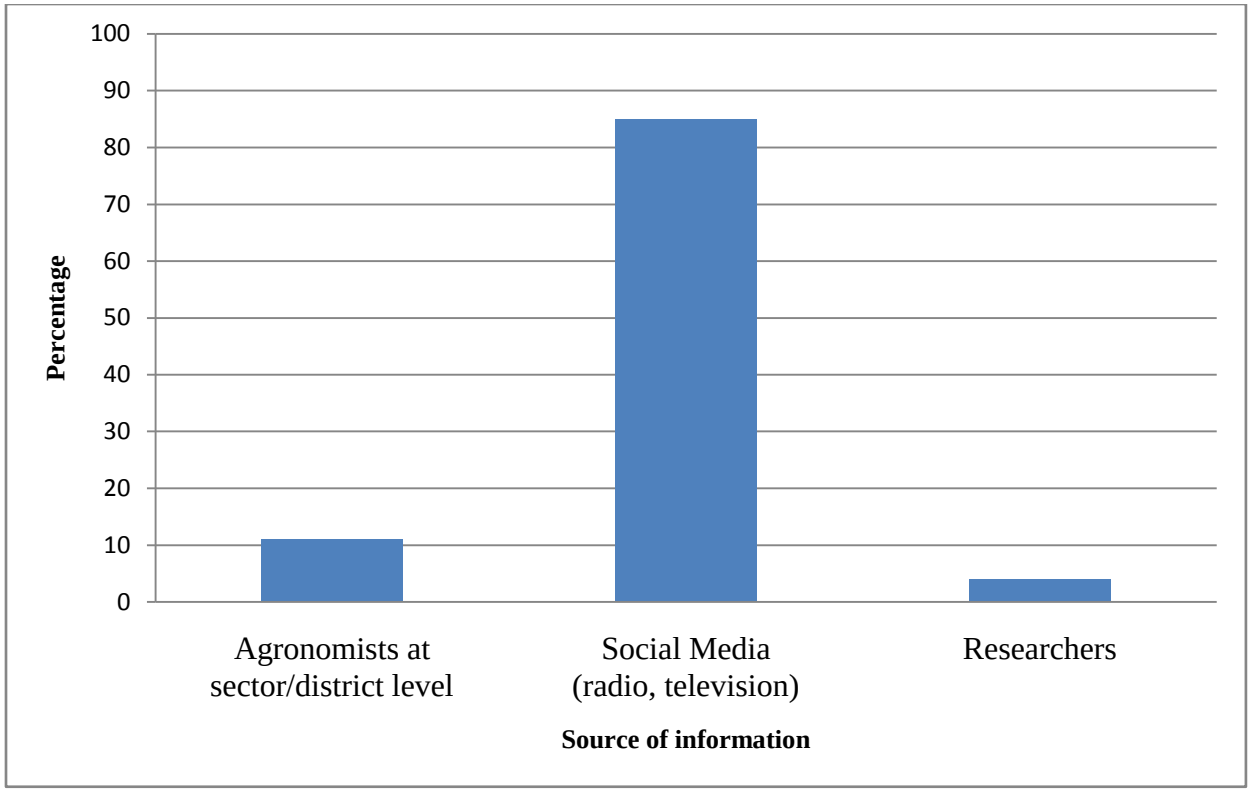

Figure 7: Source of Information on Climate Variability in the Study Area (Field, 2016)

Access to climate variability related information is one of the important aspects that may serve to explain adaptive capacity of an individual or a community (Phillips, 2003). The collected data revealed that the source of information on climate variability in the study area goes with a tally of 85% of respondents that reported that they get information by national media such as radio and television; agronomist meeting with the rice farmers ranked at the second place with 11% while 4 % of respondents reported getting information from researchers.

Regarding the question related to the respondents' views on variability of climate in the study area, 88 % confirmed that there is a change on local climate while the remaining 12% were reported that there is no change of climate. This was supported by the Environmental officer at district level who confirmed the rice farmers' perceptions as follows: "*the variability of climate is very seen in Bugesera region; nowadays we have a prolonged dry seasons and much unpredictable rainfall comparing to ten year ago. As result, this variability's tremendously affects local rice farmers and it is true to say that Bugesera District is exposed to climate variability due to its geographical aspects and external factors*".

Finally, the surveyed rice farmers were asked about the observed major climate variability parameters (or phenomena) over the past 30 years and, in total, 15 phenomena have been indicated by categorizing them as increasing, decreasing, and no change.

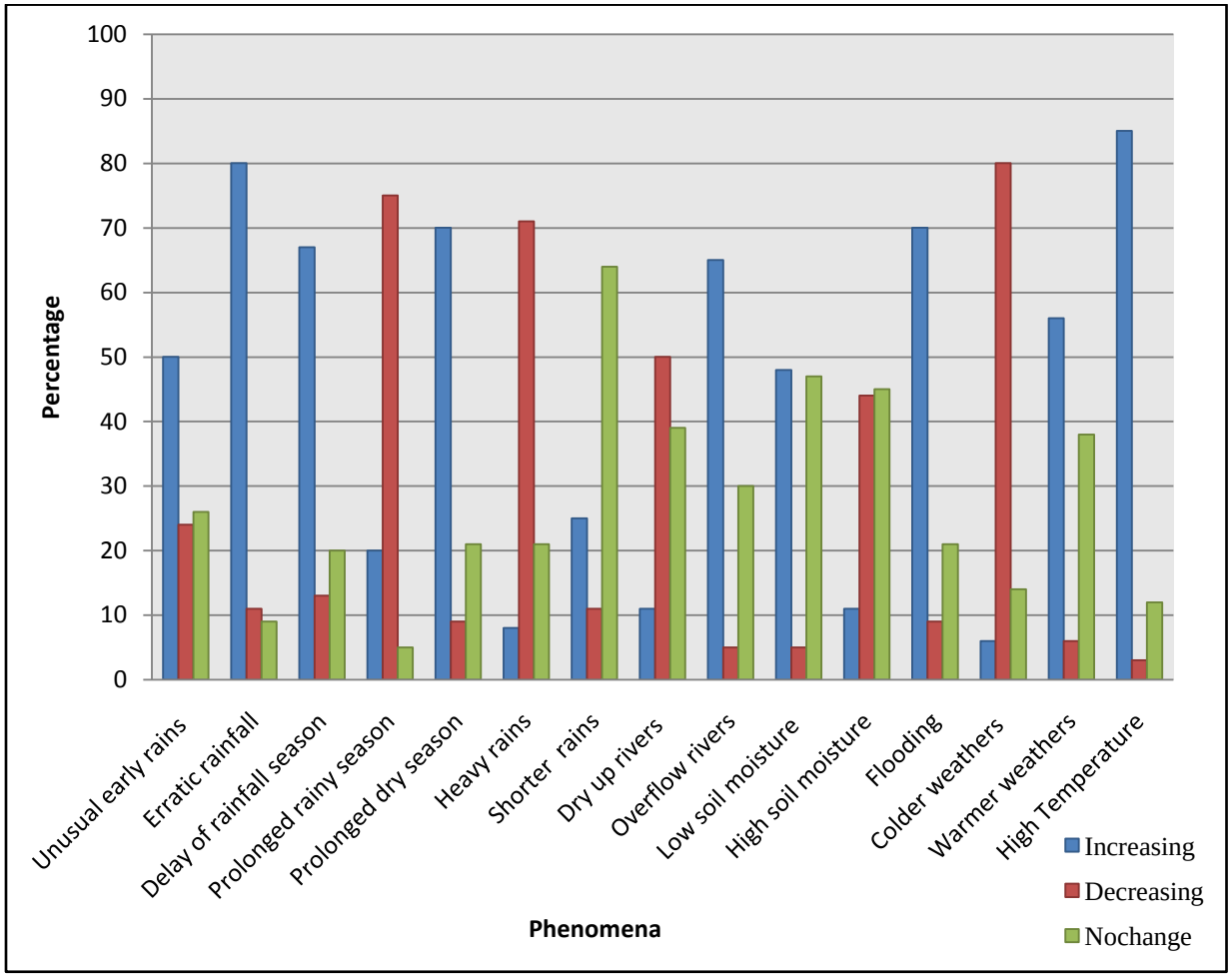

Figure 8: Observed Climate Variability Parameters over the past 30 years (Field Survey, 2016)

Results showed that over the past 30 years there were the high increase mainly on high temperature, erratic (unpredictable) rainfall, prolonged dry season and flooding with 85%, 80%, 70% and 70% respectively. On other hand the study revealed that some other phenomena like colder weather, prolonged rainfall season and heavy rains have been decreased during last three decades as reported by 80, 75 and 71% respondents respectively. The increases of these climatic parameters are the triggers by the drought phenomenon.

Results from this study are supported by UNEP (2011) that noted that droughts in Rwanda are mainly triggered by a prolonged dry season or a delay in the onset of the rainy season. Finally, the surveyed rice farmers were asked to identify the type of climatic hazards they have been facing over the past 30 years and 80 % among them were identified drought phenomenon as the major climatic hazard in the study area.

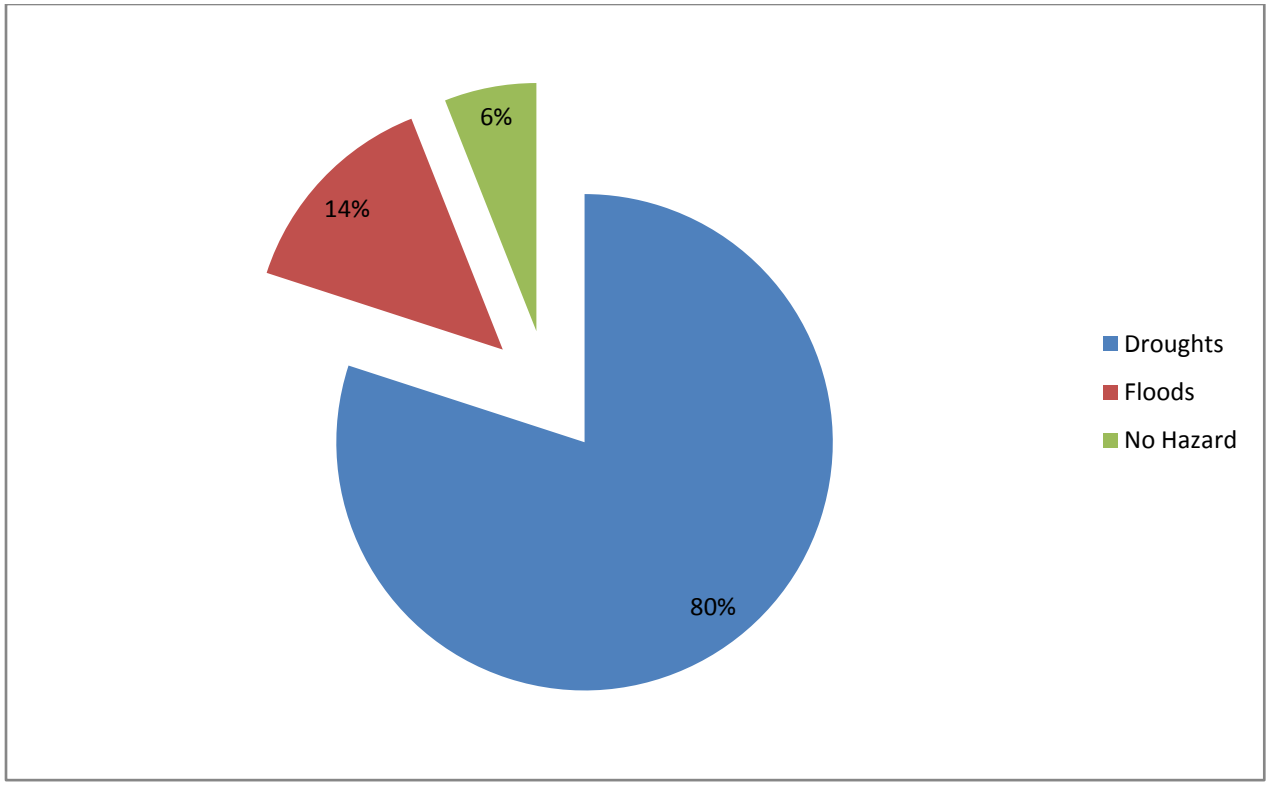

Figure 9: **Major Climatic Hazards in Bugesera District** (Field Survey, 2016)

4.1.3. Effects of Climate Variability on Rice Production

4.1.3.1 Effects related to Temperature Variability

Boko *et al*. (2007) observed that higher temperatures reduced crop yields by subjecting plants to greater stress, and increasing evaporation of moisture in the soil leading to the increasing the risk of crop failure. Temperature change affects rice crop production adversely. Drought shortens the phenological phase of crop and effects of course rice plant growth and development (Liu et *al*., 2010). High temperature in Bugesera region affects negatively rice seedling, seed germination, germination rate and lead to development of pests and diseases

Table 3: **Impact of Prolonged Drought on Rice Production**

Effect on Rice	Frequency
Failure to germinate	50
High rate of rice diseases and pests	20
Increased crop withering	4
Premature ripening	11
Reduced production cycle	15
Total	**100**

Source: Field Survey (2016)

From the table 3, 50% of respondents declared that rice farmers in Bugesera District faced the problem of failure germination for their rice due to high temperature while 20% reported that high rate of rice diseases and pests have been increased in the study area. 15%, 11%, and 4% indicated that they have been challenged by reduction of rice production cycle, premature ripening and crop withering respectively. These views were supported by the observations made by local agronomists of two cooperatives of rice farming in the study area where they indicated that rice requires sufficient water to grow, and rainless lowland rice growing areas can significantly reduce rice yields and high temperature cause the failure germination of rice. Their arguments are detailed in the following citation: *"Here at Nyaburiba wetland, we face the problem of high temperature and we rely on water from small natural river to irrigate our rice plantation. We do not have water reservoir or dam even to collect water. This problem of high temperature leads to water shortage and cause the development of pests and diseases to our rice plantation"*.

4.1.3.2 Effects related to Rainfall Variability

The change in the rainfall pattern (increasing or decreasing) in the study area has negatively affected production of rice (Rwanyiziri & Rugema, 2013). The shortage of water which is linked to the decreased rainfall and the decline in amount of water supply especially in the long dry seasons has far reaching effects on the production of rice. Rice is unique that it can thrive in wet conditions where other crops fail. Uncontrolled flooding is a problem, however, because rice cannot survive if submerged under water for long periods of time. 63 % of respondents indicated that floods hind rice crop damage and 20 % declared that floods also cause poor germination of rice.

Finally, rice famers reported also that rainfall causes the increase of rice disease and prolonged production cycle.

Table 4: **Impact of Floods on Rice Production**

Effect on rice	**Frequency**
Increased rice disease	12
Poor germination rate	20
Prolonged production cycle	5
Rice crop damage	63
Total	**100**

Source: Field Survey (2016)

The study conducted by Rwanyiziri and Rugema (2012) found out that Akanyaru river is continuously filled up and cause flooding to nearest rice plantations especially Ruvubu and Nyaburiba wetlands due to the imbalance between discharge and natural recharge. Some parts of these wetlands have filled up with water and are no longer in use for rice production. This statement was confirmed by the local agronomist who regretted the loss 30 ha dedicated to rice cultivation due to recent flooding phenomena. He continued saying that it is a big loss for local rice farmers and the country as whole.

Figure 10: **Flooded Area in Ruvubu Wetland – Bugesera District** (Author, 2016)

To the question on knowledge the effects of both floods and droughts on rice production in order to know at what extent rice diseases and pests have been affecting the rice production in Bugesera District, the majority of respondents (53%) indicated that floods and droughts are the main cause of rice crop damage. 30%, 12 % and 5% reported increased diseases, poor germination rate, and prolonged production cycle respectively. Indeed, rice diseases and pests are strongly influenced by climate variability. Water shortages, irregular rainfall patterns, and related water stresses increase the intensity of diseases.

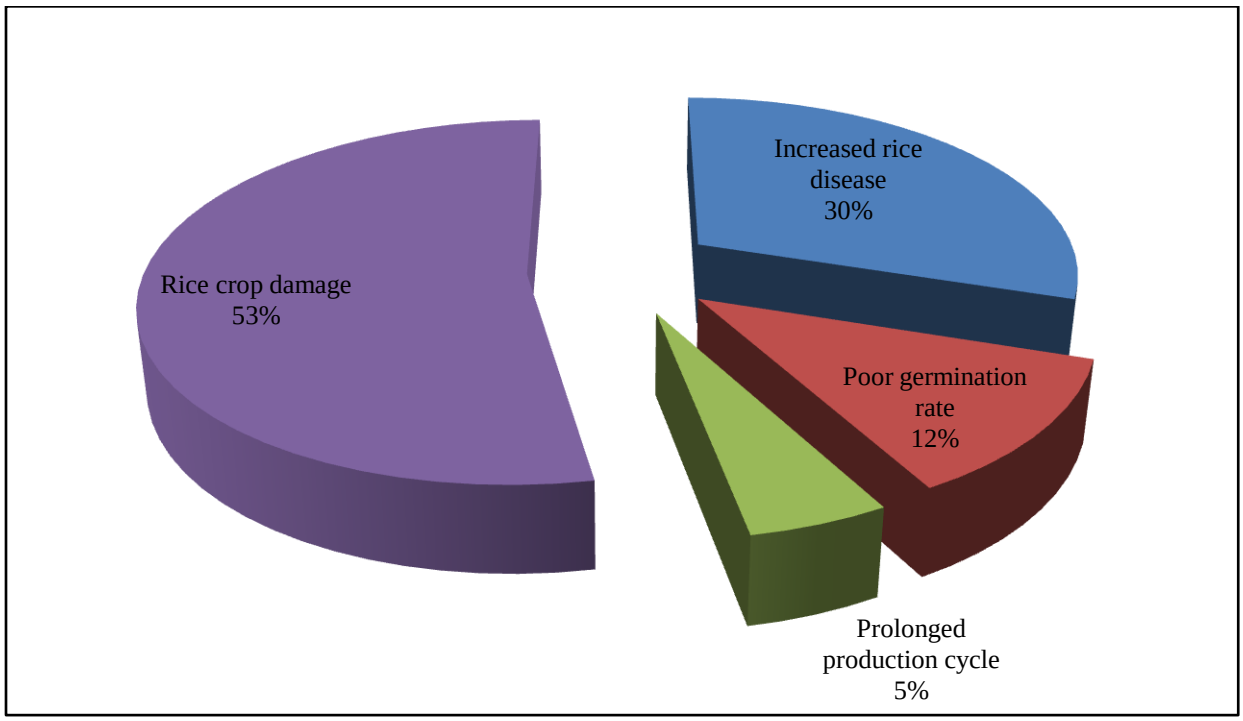

Figure 11: Impacts of Floods and Droughts on Rice Production in Bugesera District (Field, 2016)

The increase in both frequency and intensity of climatic phenomena including temperature and rainfall, along with its variability, is emerging as a potential threat to the sustainability of rice production (Jagadish et *al*., 2010b). To assess the effect of temperature and rainfall variability on rice production in Bugesera District, the research considered ten years from 2005 to 2014 of rice production from Nyaburiba cooperative. From the graph of rice production for the last decade in Bugesera District, it shows the trends of climatic conditions and rice production. According to the figure 12 of rice production vs. temperature it shows a decrease and increase of rice production depending on the increases and decreases of temperature respectively.

The same case figure 13 of the production of rice vs rainfall it shows a decrease of rice production due to short rainfall.

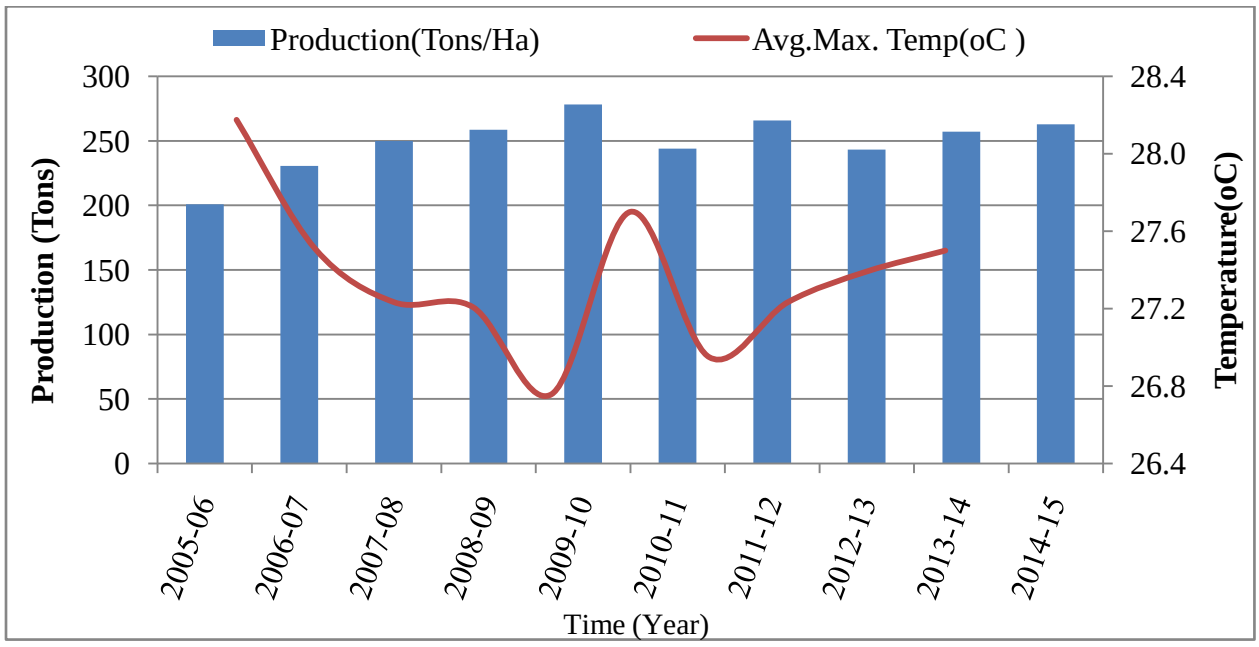

Figure 12: **Relationship between Temperature (ºC) and Rice Production for CORI Nyaburiba (2005 – 2014)**

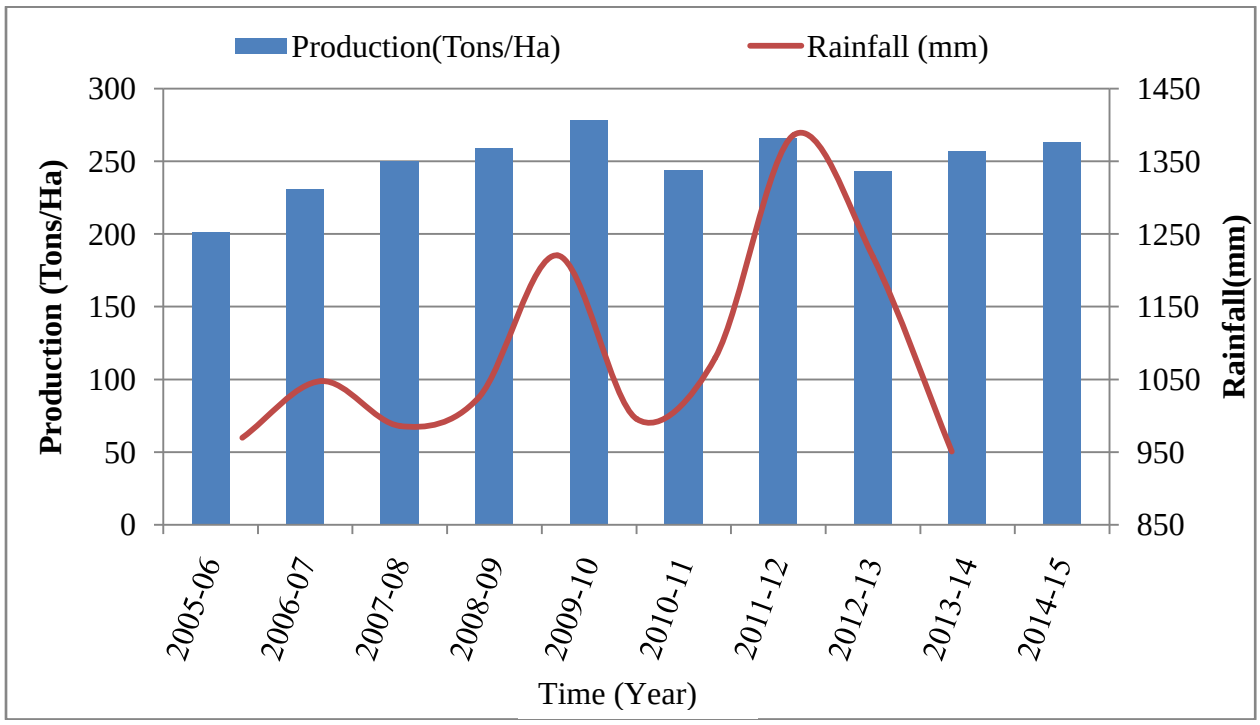

Figure 13: Relationship between Rainfall (Pmm) and Rice Production for CORI Nyaburiba (2005 – 2014)

4.2. Socio-economic Vulnerability of Rice Farmers to Climate Variability

This subchapter is analyzing major types of socioeconomic vulnerability to climate variability effects as well as their consequences on rice farmers in Bugesera district. In addition to this, it describes major groups who are most socio-economically vulnerable to those effects.

4.2.1. Types of Socio-economic Vulnerability

Research findings of this study showed that rice farmers are socio-economically vulnerable to the effects of climate variability when the rice production decreases in the study area. This has also a negative impact on the quantity of meals as it has been reported by 80 % of respondents. The other types of socio-economic vulnerability are poor quality of meals and high prices of food at markets, among others.

Table 5: **Types of Socioeconomic Vulnerability**

Type of Socio-economic Vulnerability	Yes (%)	No (%)
High prices of food at markets	60	40
High robbery of food and livestock	30	70
Increased cases of malnutrition	50	50
Increased family conflicts due to food shortage	20	80
Poor quality of meals	70	30
Reduced number of meals per day	40	60
Reduced quantity of meals	80	20
Rural exodus towards green pastures/urban areas	10	90

Source: Field Survey (2016)

4.2.2. Consequences of Socio-economic Vulnerability among Rice Farmers

Changes in the environment affect consumption of rural livelihoods through their impacts on rice production and income, since paddies are directly affected by climate variability (Skoufias and Vinha, 2012). Climatic variability can also impact food security at the macroeconomic level through its effect on economic growth. In their respective studies, Dell et *al*. (2008) and Mendelsohn et *al*. (2006) have shown that climatic variability has large and negative effects on economic growth in the poor countries.

For the case of Bugesera district, it has noticed that flooding in the rainy seasons and droughts in the dry seasons have been affecting the growth of rice and leading to food insecurity. In fact, as rice is increasingly becoming a major source of food for many households the problem of food insecurity become worse among rice farmers when climatic hazards happen. This was revealed by 90 % of respondents where they indicated that the reduction of rice production leads to food crisis not only in their respective families but also in the whole district.

Beyond the problem of food crisis in the district, 85% of respondents reported that they sometimes fail to pay school fees for the children. Others consequences include the difficulties of paying medical insurance fees and/or the recruitment of new staff to be enrolled in farming related activities at the beginning and/or at the end of each agricultural season.

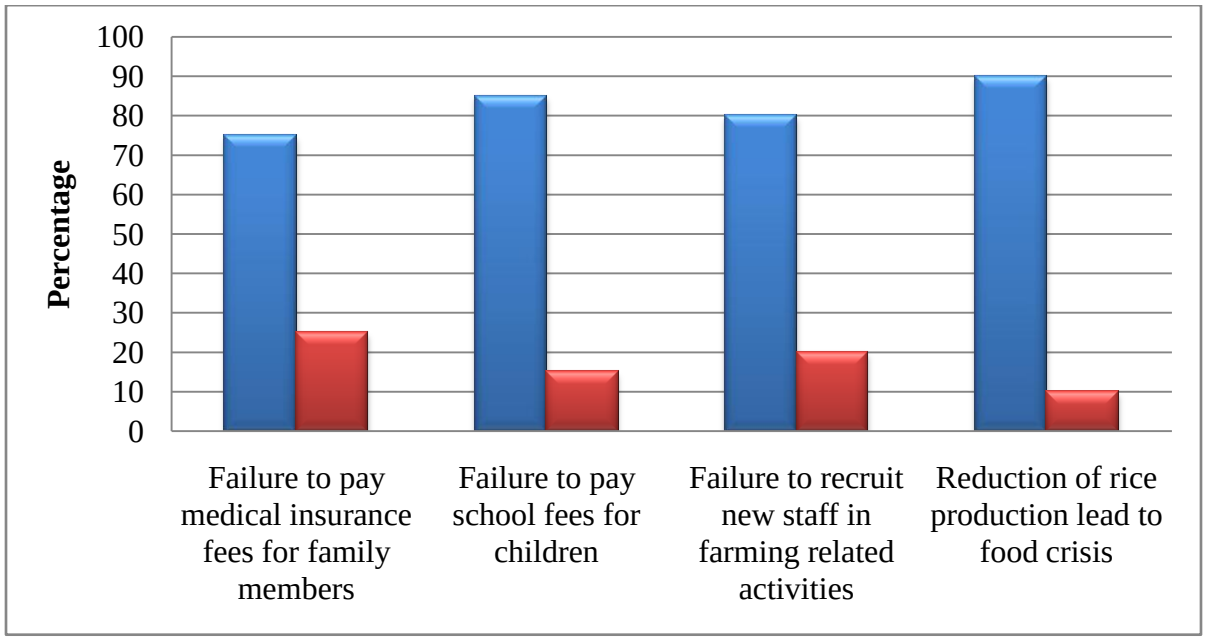

Figure 14: Socio-economic Consequences related to Low Rice Production (Field Survey, 2016)

4.2.3. Categories of Socio- economic Vulnerable Groups

Vulnerability is not a static phenomenon. Some community members may be more vulnerable than others, despite the entire community being vulnerable.

Different scholars like Kyazze and Kristjanson (2011); Yacine *et al*., (2011); Mwangangi *et al*., (2012) have been glanced on the issue saying that men and women share in the food production

responsibilities, where men are primarily responsible for cash crops and cattle, and women are primarily responsible for fuel wood and manure collection. Furthermore, women's property rights to land vary between countries and across regions within a country. However, land tenure systems and the availability of funds to invest in improved technologies are some of the common gender-sensitive problems predominantly faced by women farmers that constitute major barriers to the adoption of conservation agriculture on climate variability.

For the case of this study, it has been noticed that women (60 %), children (14 %) and girls (12 %) are the most socio-economic vulnerable groups to the effects of climate variability in the study area. This top three is followed by youth (10 %) in general and men (4 %). For ***women***, it is known that traditional beliefs and practices in Rwandan community are still marginalizing women on access to food, access to loan, access to some livelihood assets, etc. This is somehow unfair because women (55 %) are more involved in rice production than men (45 %) in the study area. For ***girls***, the Rwandan culture comes in once again where some families give advantages or privileges to boys than girls. This is the case when there is problem of school fees for example. Regarding ***youth***, it is known that youth are socio-economic vulnerable due to the problem of unemployment. Their situation is currently exacerbated by the effects of climate variability in the region.

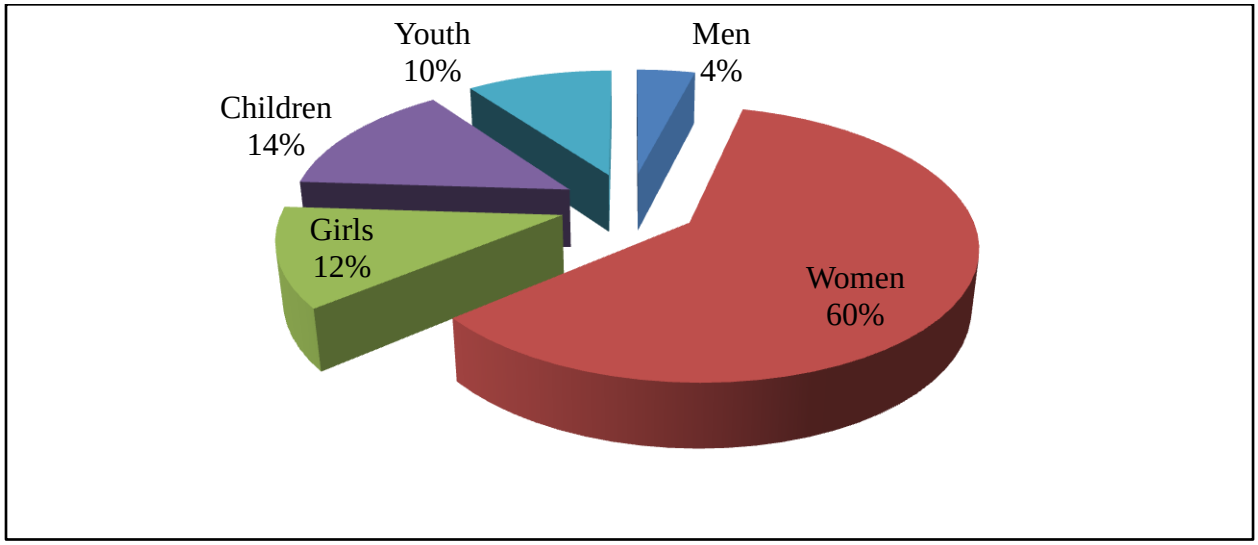

Figure 15: **Socio-economic Vulnerable Groups to Climate Variability Effects**

4.3 Rice Farmers' Existing Adaptation Strategies to Climate Variability

Since climate variability is already underway, we need adaptation policies to complement mitigation policies. Efficient implementation of adaptation strategies can significantly reduce adverse socio economic impacts of climate variability on paddy rice farmers. Without adaptation, climate variability is generally detrimental to the agriculture sector; but with adaptation, vulnerability can largely be reduced (Glwadys, 2009). The degree to which an agricultural system is affected by climate variability depends on its adaptive capacity. Indeed, adaptive capacity is the ability of a system to adjust to climate variability and extremes to moderate potential damage, to take advantage of opportunities, or to cope with the consequences (IPCC, 2001).

4.3.1 Adaptation Strategies on Prolonged Droughts

Smallholder rice farmers have adopted different adaptation strategies to cope with the Impact of drought such as investing in irrigation mechanisms, use of drought resistant rice varieties (25%), early maturing rice varieties, intensive use of manure and compost, diseases and pest's resistant rice varieties and use of pesticides and insecticides. Irrigation is the commonly used adaptation measure (52%). The following figure is summarizing the existing adaptation strategies when there is a prolonged drought.

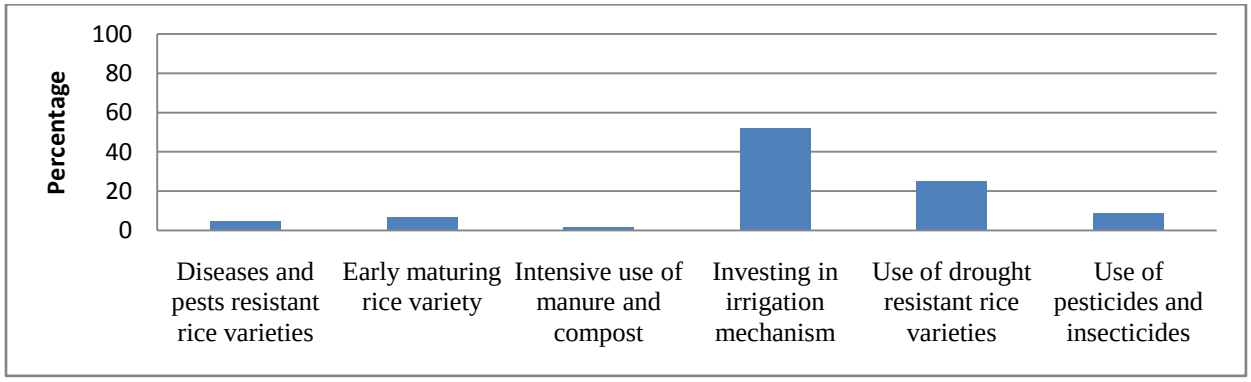

Figure 16: **Rice Farmers' Adaptation Strategies on Prolonged Droughts** (Field Survey, 2016)

Respondents reported that they have access to fertilizers and pesticides through cooperative. They apply mineral fertilizers to grow rice in the wetland. Commonly used fertilizers were NPK (17-17- 17) and urea. NPK was used during rice plantation and urea for weeding rice. According to Sahel (2014), fertilizer supplies nutrients to the soil are essential for growth.

Increased use of fertilizer and improved seeds are partially credited with the large increases in agricultural productivity growth.

4.3.2 Adaptation Strategies on Flooding

The following figure shows the adaptation measures in the case of flooding. The results revealed that many rice farmers solve the problem of floods by investing in drainage system (77%). Other adaptation strategies on flooding are related to river banks protection (8%) and growing water-logging resistant crop varieties (15 %) as summarized in the following figure.

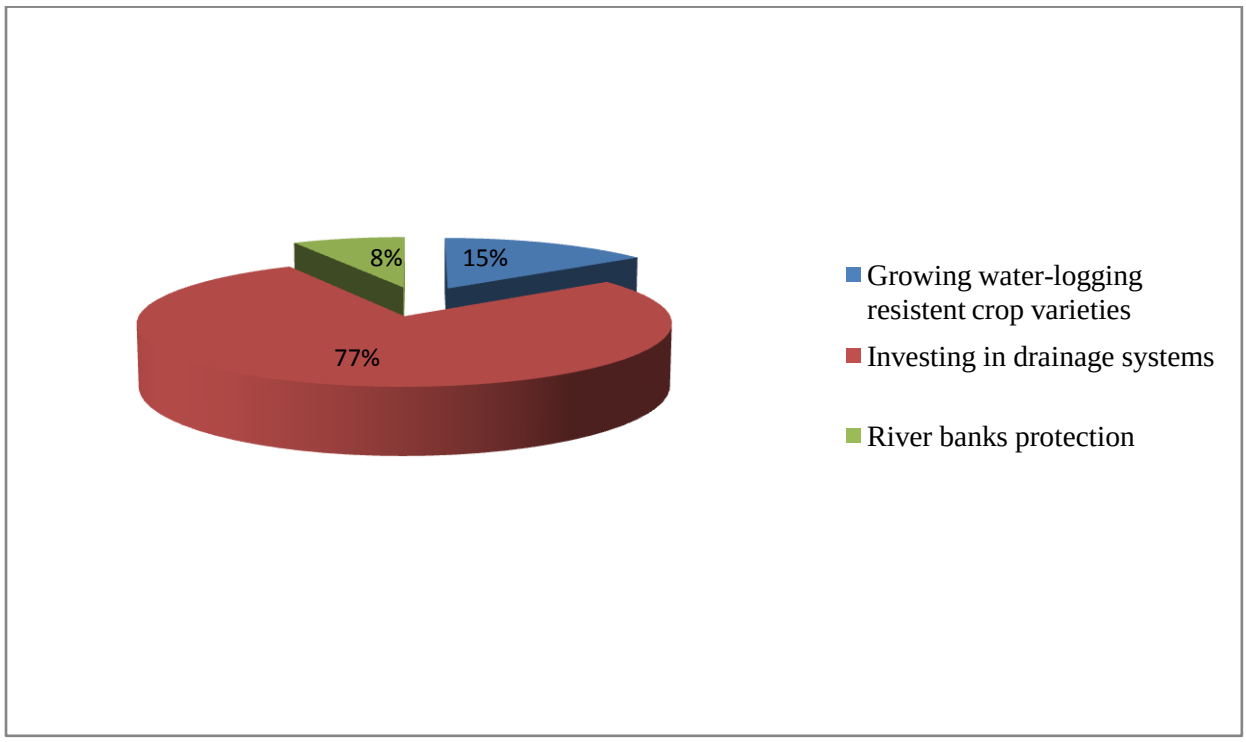

Figure 17: **Adaptation Measures on the Impacts of Flooding** (Field Survey, 2016)

4.3.3 Constraints to Adaptation and Proposed Strategies

4.3.3.1 Constraints to Adaptation

Adaptation is inevitable to address the impacts of climate variability but adaptation efforts are impeded in many ways. Constraints to adaptation hamper people's ability to address the negative impacts of climate variability or manage risks in a way that maximizes their wellbeing (Islam *et al*, 2013). Rice farmers outlined the most important constraints as expensive farm inputs like improved seeds, fertilizers, pesticides (33%) and poor information on early warning system

(21%). Others important constraints to adaptations were insufficient government subsidy for farming inputs and limited knowledge and skills about climate variability adaptation strategies.

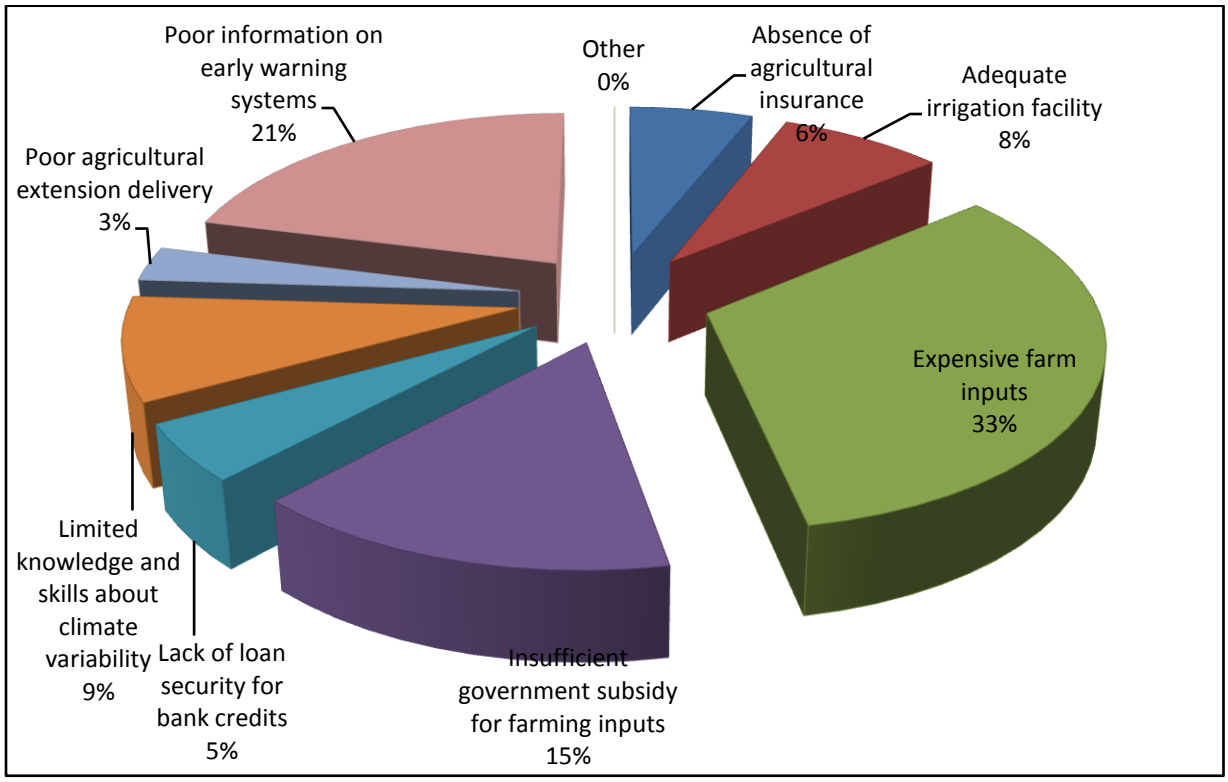

Figure 18: **Constraints to Adaptation on Climate Variability**

4.3.3.2 Proposed Adaptation Strategies

Vulnerability provides a means of understanding how the impacts of climate variability can be distributed, primarily to identify how vulnerability can be reduced, i.e., the focus is on adaptive capacity and systemic properties and solutions can be found in sustainable development (Kelly and Adger, 2000). For the case of Rwanda the Ministry of Natural Resources (MINIRENA) set out the environmental protection policy such as river banks are protected at 10 meters to avoid encroachment on water and other resources and Wetlands/ marshlands are protected at 20 meters to avoid encroachment on biodiversity. These measures will help rice farmers in adaptation process as far as it is concerned. Smallholder rice farmers were asked to identify the major sustainable solutions to reduce the vulnerability to climate variability effects in the study area and their view were recorded in table 6.

The majority of respondents pointed out that strengthening groups saving and loaning schemes and public support for irrigation infrastructure should be increased and affordable agriculture

inputs should be taken into account for better sustainable solution to climate variability effects in Bugesera Districts. The study notes that there was also a need to enhance the improve extension services on climate variability effects and availing disease and pest resistant varieties in food production for smallholder rice farmers to be transformed into a more commercial sector. The other sustainable solutions are represented in table 6.

Table 6: **Sustainable Solutions to Climate Variability Effects**

Proposed Adaptations Strategies	**Yes (%)**	**No (%)**
Adequate rice value chain	40	60
Affordable agricultural inputs	89	11
Availing disease and pest resistant varieties	75	25
Availing drought resistant rice varieties	71	29
Availing farming insurance	20	80
Creation of more off-farm activities	63	37
Improve extension services on climate variability effects	79	21
Increased access to farm credits	37	63
Increased public support for irrigation infrastructures	95	5
Set up a public agriculture fund	40	60
Strengthening groups saving and loaning schemes	98	2

Source: Field Survey (2016)

The table above is highlighting some proposed adaptation strategies to the effects of climate variability in the study area. However, three of them seem to be more important than others:

- ***Strengthening Groups Saving and Loaning Schemes:*** The participation in group saving and loans of Bugesera rice farmers lead to planning for the future, about anticipating and preparing for possible risks and emergencies like bad harvest, preparing for upcoming events and expenditures like paying of school fees or starting a new business in adaptation techniques.

- ***Increasing public support for irrigation infrastructures:*** Irrigation infrastructures in Bugesera District as drought prone area contribute a lot to rice farmers to meet their needs in agriculture process by increasing annual rice production incomes, expenditure and welfare. It provides considerable benefits to the households and contributes substantially towards poverty reduction through income and consumption.

- ***Putting in place affordable agricultural inputs:*** Affordability to agricultural inputs increases agricultural production growth of farmers of Bugesera District and is the way for adaption to climate variability and change.

4.4 Resilient Strategies to Socio-economic Vulnerability among Rice Farmers

To develop Climate-resilient is related to adding considerations of climate variability to development decision-making for ensuring that progress toward development goals now includes consideration of climate impacts (USAID, 2014). Resilience comes from having the capacity to adapt (respond to change). It signifies the capacity of a system to absorb disturbances and surprises. It can mean the ability to reorganize so as to retain the same essential function, structure and identity.

The study was conducted on smallholder rice farmers and the results show that rice farmers have their different ways of resilience to reduce socio- economic vulnerability to climate variability. As identified by the rice farmers themselves in the figure 19, the majority of respondents declared that participation of group savings and banks (97%) were the main source of resilience to climate variability. 92%, 85%, and 83% reported domestic animals raising, production of others crops and community food store/reserves. Others climate residence reported were engagement in off farm activities, crops mulching and intercropping practices in upland.

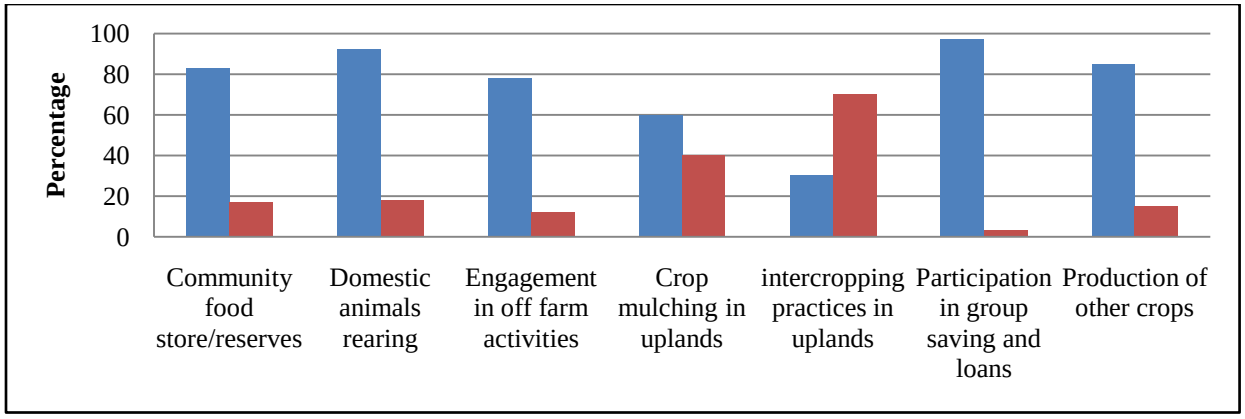

Figure 19: **Resilient Strategies to Socio-economic Vulnerability** (Field Survey, 2016)

Crop production is an important source of rural livelihood for the majority of rural people. A part from rice production in wetland, rice farmers grow also different types of crops in upland to help them when there is the losses of rice production see the table 7. The research revealed that beans are the main crop grown in three sectors of Nyarugenge, Ruhuha and Shyara. As it has been mentioned by the respondents about 56% indicated that they grow beans. Although few of them (9%) indicated that they grow sorghum and potatoes in the upland plots this due to the facts that sorghum and potatoes are not among of selected high-potential food crops for crop intensification and land use consolidation. Indeed, in 2007 government of Rwanda introduced a programme to encourage people to grow the selected high-potential food crops to increase productivity, ensure food security and transit from subsistence to commercial farming. Other crops found in the study area representing 26% including mainly maize, groundnuts, banana and few cassavas.

Table 7: Main crops grown in upland (Field Survey, 2016)

Sector	Beans	Potatoes	Sorghum	Vegetables	Others	Total
Nyarugenge	22	2	2	4	10	**40**
Ruhuha	22	0	1	0	5	**28**
Shyara	12	2	2	4	11	**32**
Total	**56**	**4**	**5**	**8**	**26**	**100**

Source: Field Survey (2016)

CHAPTER FIVE: CONCLUSION AND RECOMMENDATIONS

This chapter summarizes main findings and their implications, and suggests some strategies and actions that can shrink the impact of climate variability within the study area.

5.1. Test of Hypotheses

After the analysis of the findings of this study some hypotheses have been accepted and other rejected.

1. There is variability in rainfall and temperature patterns in the study area.

However, the analysis of temperature and rainfall patterns and the findings of the study showed an increasing of temperature trend and the annual mean rainfall is in the decreasing trend and effect local rice farmers in Bugesera District. From these analysis and findings, the hypothesis 1 is therefore accepted.

2. Rice farmers of Bugesera District are vulnerable to the effects of climate variability.

The findings of the study however showed that rice farmers of Bugesera district are socio-economically vulnerable to climate variability due to prolonged drought causing high rate of rice diseases and pests and flooding. From these findings, hypothesis 2 is therefore accepted.

3. There are difficulties in adaption measures to cope with climate variability effects in the study area.

From the study findings, it was found out that rice farmers of Bugesera District have different ways of adaption strategies to cope with climate variability effects. From these findings, hypothesis 3 is therefore rejected.

5.2 Conclusion

The objective of this study was to assess the socio-economic vulnerability of smallholder farmers to climate variability effects in Rwanda by focussing on rice farmers in Bugesera District. Statically, the analysis of temperature and precipitation of Kigali airport station shows the trend of increase of temperature. Rainfall is characterized by unusual irregularity with the decrease in the amount rainfall over 30 years.

Socio- economically, these fluctuation impact adversely on rice farmers where the results reveal that 90% noticed the reduction of rice production lead to food crisis, 85% confirmed that they sometimes failure to pay school fees for the children. Others consequences included the difficulties to pay medical insurance fees and to recruit new staff in farming related activities.

Farmers' perceptions on climate variability are in line with climate data records. Indeed, smallholder rice farmers in Bugesera are able to recognize that the big increases mainly on high temperature, erratic (unpredictable) rainfall, prolonged dry season and flooding caused by Akanyaru River with 85%, 80%, 70% and 70% respectively. The main source of information on climate variability within the study area goes with a tally of 85% of respondents that reported to get information by social medial such as radio and television and this can change a lot on climate variability in the study area. Access to information on climate variability contributes to the adaptation to local rice farmers.

Main adaptation strategies of rice farmers in Bugesera District are investing in irrigation mechanisms, use of drought resistant rice varieties, early maturing rice varieties, diseases and pest's resistant rice varieties and use of pesticides and insecticides. Even if climate variability in the study area affect all people, Our results reveal that women (60%) are more vulnerable category than men (4%) as indicated by the respondents. Others vulnerable group are children (14%), Girls (12%) and youth (10%). Despite of the adversely impacts of climate variability, rice farmers of Bugesera pointed out the measure sustainable solutions to climate variability, including the increase of public and government support for irrigation infrastructure and affordable agriculture inputs.

5.3. Recommendations

This study has assessed the socio-economic vulnerability of smallholder farmers to climate variability effects in Rwanda by focussing on rice farmers in Bugesera District. Based on the results presented in chapter 4, the following recommendations are made for maintaining or improving rice production in Rwanda in face of climate variability.

1) Improvement should be strengthened on climate variability monitoring and preparedness, which should be incorporated with local knowledge, assessments of the vulnerabilities,

risks and impacts, on local smallholder farmers that form the majority of the rural population and early warning information in droughts, floods and temperature rise management.

2) The government of Rwanda should invest much in irrigation infrastructure (inadequate water shortage capacities especially in eastern should be in form of dams for increasing irrigation during dry season in wetlands).
3) Access to agriculture inputs, Availing disease and pest resistant varieties and strengthening groups saving and loaning schemes were found to be sustainable solution to climate variability related rice production loss. Government policy should take into consideration these factors.
4) The study revealed that rice farmers who have education background are able to understand and more capable of adapting easily to climate- related shocks. Government could speed up and implement an agricultural education policy so that uneducated farmers receive suitable knowledge on extension services and new technologies for climate variability adaptation.
5) Smallholder rice farmres of Bugesera District should be sensitized much on climate variability and its impact on rice crop production and livelihoods. The residents should be trained to identify and develop strategies for mitigating against impact of climate varibility at the local level.
6) More research should be carried out on the impact of climate variability on diffent crop that can resist to drought, pests and diseases to reduce the effect of food insecurity in Bugesera District.

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ANNEXES

A. Questionnaire for Rice Farmers

I. Identification of Respondent

- Questionnaire number:
- Sector:
- Name of Cooperative:

1. Age	1=18-30;	2=31-55;	3=56 and above	**…...**
2. Gender	1= Male	2= Female		……
3. Marital Status	1= Single	2= Married	3= Widowed	…….
	4= divorced	5= Separated	6=other	
4. Education Level	1= None	2= Primary	3= Secondary	……..
	4=University	5= TVT	6= Other:	
5. Family Size	1= 1-5	2= 6-10	3=More than 10	…….
6. Occupation	1= Agriculture	2= Business/ small	3=Salaried	…….
	4= Casual jobs	5= Other…….....		

II. Questions

Section A: Question on Socio-Economic of Rice farmers

1. How long have you been living the area?

a) 1-15 years [ ] b) 16-30 years [ ] c) 31years and above [ ]

2. How many plots (or fields) do you have/ cultivate currently?

a) 1-2 fields [ ] b) 3 and above [ ]

3. Beyond rice in wetland, what are other most types of crops do you grow in upland?

a) Bean [ ] b) Sorghum [ ] c) Potatoes [ ] d) Vegetables [ ]

e) Other (specify)…….

4) Do you have access to agricultural inputs?

a) Yes [ ] b) No [ ]

5) If yes, what are the major agricultural inputs do you use?

a) Improved seeds [ ] b) Fertilizers [ ] c) Pesticides [ ]

d) Other (specify)……

6) How much of rice (in kgs) did you harvest during the last season?

a) 0-100 kgs [ ] b) 101-200 kgs [ ] c) 201-300kgs [ ]

d) 300 kgs and above [ ]

7) What is the source of labor?

a) Family members [ ] b) Hired [ ] c) Community work [ ]

d) Other (specify)……

8) Do you your family have access to health insurance?

a) Yes [ ] b) No [ ]

9) Do you your children have access to school?

a) Yes [ ] b) No [ ]

10) If no, what can be the main cause of dropping out or not attending school?

a) Family poverty [ ] b) child abuse [ ] c) Delinquency Juvenile [ ]

d) Lack of school fees [ ] e) other please specify…….

Section B: Questions on the Impacts of Climate Variability on Rice Production and Socio-economic Vulnerability

1) **Have you ever heard about climate variability? 1=Yes 2=No**	[……..]
2) If yes, in which opportunity? 1= Media (radio, television, newspapers, etc.) 2= Agronomists at sector/district level 3= Researchers 3= Other (specify)…….	[…….]

3. What are the actual climatic conditions of this area in terms of temperature and rainfall compared to the past 30 years? (Fill in the box with **X)**

- *There is a change* ☐
- *There is no change* ☐

4. If there is a change or variability, which is that variability over the past 10 years?			
Phenomena	**1. Increasing**	**2. Decreasing**	**3. No change**
1=Unusual early rains			
2=Erratic rainfall			
3=Delay of rainfall season			
4=Prolonged rainy season			
5=Prolonged dry season			
6=Heavy rains			
7=Shorter rains			
8=Dry up rivers			
9=Overflow rivers			
10=Low soil moisture			
11=High soil moisture			
12=Flooding			
13=Colder weathers			
14=Warmer weathers			
15=High Temperature			

5. Have you ever faced with any climatic hazard induced shock in your lifetime?

1= Yes ☐ *2=No* ☐

6. If yes, what type of climatic hazard?

1. Droughts ☐

2. Floods ☐

7. For the case of drought, how many times did this hazard occur over the past 30 years?

1=1-5 times ☐

2=6-10 times ☐

3=More than 10 times ☐

8. For the case of floods, how many times did this hazard occur over the past 30 years?

1=1-5 times ☐

2=6-10 times ☐

3=More than 10 times ☐

9. ***For the case of drought,*** **what happens to local farmers in the wetland agricultural zones?**

Fill the box with **Yes or No**

1= Water shortage or water stress	/……/
2=Crops withering	……
3=Increased diseases and pests	……
4=Other (specify): …….	

10. ***For the case of flood,*** **what happens to local farmers in the wetland agricultural zones?**

Fill the box with **Yes or No**

1=Destruction of irrigation infrastructure	
2=Crops damage	
3= Increased diseases and pests	
4= Other (specify): ……..	

11. In both cases of droughts and floods, who are more vulnerable groups among local farmers to the impact? ***(Yes or No)***

1= Maize Farmers	**/…./**
2= Rice Farmers	**/…./**
3=Vegetable growers	**/…./**
4=Beans and soybeans growers	**/…./**
5=Other (specify)…….	

12. ***For the case of rice farmers in this area,*** **what happens to the rice crop when there is a prolonged drought?**

Possible Answers	**Yes /No**
1= Failure to germinate	
2=Premature ripening	
3=Reduced production cycle	

4=High rate of rice diseases and pests	
5=Increased crop withering	
6=Other (specify):	

13. What happens to the rice crop when there is a flood?

Possible Answers	**Yes or No**
1=Maize crop damage	
2=Poor germination rate	
3=Increased rice diseases	
4=Prolonged production cycle	
5=Other (specify): ……	

14. In both cases of floods and droughts, at what extent diseases and pests have affected the rice production? Respond with Yes or No

1=Reduced rice yields	
2=Poor quality of rice grains	
5=High investment in pesticides	
6=Other (specify): ……	

Section C: Socio-economic Vulnerability to Climate Variability Effects

1. Do you see any relationship between rice production and food security in this area?

1= Yes *2=No*	*/……../*

2. If yes, what are the major consequences when the rice production has decreased?

Possible Answers	**Yes or No**
1= Reduced number of meals per day	
2= Reduced quantity of meals	
3=Poor quality of meals	
4= Increased family conflicts due to food shortage	
5=Increased cases of malnutrition	
6= High robbery of food and livestock	

7= Rural exodus towards green pastures/urban areas	
8= High prices of food at markets	
9=Other (specify)……	

3. Do you see any relationship between rice farmers' livelihoods in this area?

1= Yes	*2=No*	*/……../*

4. If yes, what are the major consequences when the rice production has decreased?

Possible Answers	**Yes or No**
1= Reduction of rice production lead to Food crisis	
3= Failure to pay school fees for children	
4= Failure to recruit new staff in farming related activities	
5= Failure to pay medical insurance fees for family members	
6=Other (specify)……..	

5. Who is most vulnerable group to the impact? 1=Women 2=Men 3=Girls 4=Youth 5=Children 6=Landless 7= Other (specify)……	[…….]

Section D: Questions related to Climate Variability Adaptation Strategies

1. **What are the climate resilience practices are you engaged in to reduce socio-economic vulnerability to climate variability, especially when rice production has decreased?**

Possible Answers	**Yes or No**
1=Community food store/reserves	
2=Domestic animals rearing	
3=Participation in group saving and loans	
4=Engagement in off-farm activities	
5. Crop mulching in uplands	
6=Intercropping practices in uplands	

7=Production of other crops (maize, cassava, Irish potatoes, vegetables, etc.)	
8. Other (specify)……	

2. **In case of prolonged drought, which adaptation measures do you use in growing rice?**

adaptation measures in case of drought	**Possible Answers**
1=Investing in irrigation mechanisms	
2=Use of drought resistant rice varieties	
3=Early maturing rice varieties	
4=Intensive use of manure and compost	
5=Diseases and pests resistant rice varieties	
6=Use of pesticides and insecticides	
7. Other (specify)……	

3. **In case of floods, which adaptation measures do you use in growing rice?**

Adaptation measures in case of floods	**Possible answers**
1=River banks protection	
2= Investing in drainage systems	
3=Growing water-logging resistant crop varieties	
4=Other (specify)……	

4. **What are the major constraints in implementing some adaptation initiatives?**

Major constraints	**Possible Answers**
1=Limited knowledge and skills about climate variability adaptation strategies	
2= inadequate irrigation facility	
3=Expensive farm inputs (improved seeds, fertilizers, pesticides)	
4= Poor agricultural extension delivery	
5= Poor information on early warning systems	

6=Lack of loan security for bank credits	
7=Absence of agricultural insurance	
8= Insufficient government subsidy for farming inputs	
9=Others (specify)	

5. **In both cases of droughts and floods, what are the major sustainable solutions to reduce the vulnerability to climate change/variability effects?**

Possible Answers	**Yes or No**
1= Increased public support for irrigation infrastructures	
2= Availing drought resistant rice varieties	
3=Availing disease and pest resistant varieties	
4= Protect river banks with suitable shrubs	
5=Affordable agricultural inputs	
6= Adequate rice value chain	
9= Strengthening groups saving and loaning schemes	
11=Set up a public agricultural fund	
12=Increased access to farm credits	
14=Improve extension service s on climate variability effects	
15=Availing farming insurances	
16=Creation of more off-farm activities	

B. Interview Guide

1. Currently climate change and variability is a crosscutting issue. According to you, what can be the state of climate variability in Bugesera region? Can we say that Bugesera is highly exposed to climate variability?

……

……

2) Have you ever noticed the impacts of climate variability in Bugesera District?

……

……

……

3) What is the major adaptation strategies planned to climate variability?

……

……

4) What can be the constraints to the implementation of these strategies?

……

……

5) Are the smallholder farmers of Bugesera District aware of climate variability? If yes, how do you educate them in order to increase their awareness?

……

……

……

6) What are suggestions do you propose for facilitating the farmers to cope with climate variability and its effects?

……

……

Thank you

a