Adaptation to Climate Variability in the Agriculture Sector in Rwanda

Case study of Bugesera district

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Declaration

I declare that this Dissertation contains my own work except where specifically acknowledged

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Signed…………………………
Date………../…..………/2016

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Abstract

Rwanda is a hilly country of more than 90% of population relying on agriculture. The land is very scarce with an average of 0.3Ha per household. Due to land scarcity coupled with high rate of population growth the land is highly overexploited. Overexploitation together with temperature increase, shift of seasons and low rainfall in drought risk zone of Bugesera accelerates the severity of agriculture vulnerability to climate variability. All of these issues have inspired me to assess the level of adaptation to these changes to attain agriculture sustainability.

The main objective of this research was to assess the adaptation to climate variability in Agriculture Sector in Rwanda, especially in Bugesera. Exposure and sensitivity of grain legumes' yields to climate variability and ability of farmers to adapt to the effects of exposure and sensitivity of grain legumes to climate impacts have been selected as main indicators for this research.

To achieve this, cluster area sampling and random sampling were used to select 99 households surveyed using a structured questionnaire. With intention of clarifying some aspects not captured in the survey, interview was organized with local authorities in charge of agriculture and social affairs at both sector and district levels. MAKESENS model and Analysis of Variances (ANOVA) have been used to analyze climate data and information got from household survey.

This research revealed significant increase of mean temperature (0.39^{0}C and 0.46^{0}C per decade for rainy seasons A and B respectively) and irregularity of rainfalls during both rainy seasons. Diurnal Temperature Range is decreasing considerably which can impact on plant development like decrease in internode length, as well as the small decrease in height, stem thickness and leaf area could add up to a large decrease in photosynthetic area. Also the analysis of minimum and maximum temperatures dynamics per decade from 1970s indicates that so far they provide an acceptable temperature threshold for beans development but they are not optimum for peas and soybeans.

Consequently, the yield of grain legumes in Bugesera is much sensitive to climate variability because the small farmers of Bugesera do not have enough capacity of adaptation to climate change/variability due to insufficient awareness and commitment to climate variability mitigations, inefficiency of irrigation tools/equipments, traditional and subsistence agriculture, poverty, little access to information on climate change/variability, miss-believing in climate change/variability (68.7% do not believe on climate information got from any source) as well as the inefficiency of climate information communication.

For a better mitigation of climate change/variability impacts, land consolidation and forming cooperatives, improving economic capacity of local farmers, cultivating seeds that are resilient to climate variability and if possible start other off-farm activities, improving climate information reliability and dissemination as well as continuous researches should be paid greater attention.

KEY WORDS: *Bugesera*, *Climate change impacts, Climate vulnerability and Adaptive capacity*

List of symbols and acronyms

ANOVA	Analysis of Variance
CDO	Community Development Officer
CSEA	Choice Social Enterprise Africa
DTR	Diurnal Temperature Range
EDPRS1	First Economic Development and Poverty Eradication Strategy
EDPRS2	Second Economic Development and Poverty Eradication Strategy
FAO	Food and Agriculture Organisation
GDP	Gross Domestic Product
GIS	Geographic Information Systems
GoR	Government of Rwanda
HH	Households
HIMO	*Haute Intensité de la Main D'œuvre*
IDB	Inter-American Development Bank
IISD	International Institute for Sustainable Development
IPCC	Intergovernmental Panel on Climate Change
IUCN	International Union for Conservation of Nature
MINAGRI	Ministry of Agriculture and Animal Resources
M**INIRENA**	Ministry of Natural Resources
MINITERE	Ministry of Lands, Environment, Forests, Water and Mining
NDVI	Normalized Difference Vegetation Index
NGOs	Non-Governmental Organizations
NISR	National Institute of Statistics of Rwanda
PADAB	*Projetd'Apui au Dévelopment Agricole de Bugesera*
PSU	Primary Sampling Unit
REMA	Rwanda Environment Management Authority
RMC	Rwanda Meteorological Centre
Rwf	Rwandan Francs
SEDO	Socio-Economic Development Of cell
SEI	Stockholm Environment Institute
SPSS	Statistical Package for the Social Sciences
UKCIP	United Kingdom Climate Impacts Programme
UNDP	United Nations Development Programme
UNEP	United Nations for Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
USAID	United States Agency for International Development
WFP	World Food Programme

Contents

List of tables

List of figures

CHAPTER ONE: INTRODUCTION

This research is oriented in environmental concern for rural community advocacy dealing with Adaptation to Climate Variability in Agriculture Sector in droughts risk zones like Bugesera in Rwanda. The first chapter of this research describes the background information of the study, problem statement, research objectives, questions and hypothesis then illustrates the research significance.

1.1. Background information

Nowadays scientists, economists, and policy makers of the entire globe are facing real and serious long-term threats from climate variability/change. In agriculture sector, most of the projections estimate that, by the end of the 21st century climate change will have significant impacts on agricultural production (Slater, et. al., 2007). Thus, strong measures and practices to ensure agricultural sustainability are advised to planners and decision/policy makers at national, regional and global levels.

Referring to Hulme *et al* (2000)'s reviews and observations there were past changes(1900-2000) as well as possible future (2000-2100) continent-wide changes in temperature and rainfall for Africa; the climate of Africa was warmer in the year 2000 than it was in 1900. This has occurred at the rate of about 0.5^{O}C per century and the six warmest years have occurred since 1987, with 1998 being the warmest year. The 21st century picture therefore remains almost the same with predicted annual warming across Africa of slightly below 0.2^{O}C to over 0.5^{O}C per decade (Hulme *et al,* 2000). New *et al.* (2006)'s analysis of the daily temperature (maximum and minimum) and precipitation data from 14 south and west African countries over the period 1961–2000 confirms that there is evidence of daily climate extremes over western and southern Africa (where Rwanda is located). In these two regions, New *et al* (2006) discovered that extreme cold day and nights have decreased whereas hot days and nights have increased. As of rainfall, average dry spell length, average rainfall intensity, and annual 1-day maximum rainfall all show statistically significant increasing trends (IISD, IUCN & SEI, 2003). This indicates an increased trend in the likelihood of the occurrence of weather hazards, such as heavy storms leading to floods, high temperatures, and both seasonal and mid-rainy season droughts that agriculture and other sectors have to contend with (Cannon, 2010).

Africa is already a continent under pressure from climate stresses and is highly vulnerable to the impacts of climate change. Many areas in Africa are recognized as having climates that are among the most variable in the world on seasonal and decadal time scales (Slater, et. al., 2007). Floods and droughts can occur in the same area within months of each other. These events can lead to famine and widespread disruption of socio-economic well-being. Many factors contribute and compound the impacts of current climate variability in Africa and will have negative effects on the continent's ability to cope with climate change (Morton, 2007). These include poverty, illiteracy and lack of skills, weak institutions, limited infrastructure, lack of technology and information, low levels of primary education and health care, poor access to resources, low management capabilities and armed conflicts(UNDP 2006). This author also argued that the overexploitation of land resources including forests, increases in population and land degradation pose additional threats.

However, Africa will face increasing water scarcity and stress with a subsequent potential increase of water conflicts as almost all of the 50 river basins in Africa are transboundary (Ashton 2002). Agricultural production relies mainly on rainfall for irrigation and will be severely compromised in many African countries, particularly for subsistence farmers and in sub-Saharan Africa (De Wit and Jacek 2006).

Although there is still a significant uncertainty regarding the climate change scenarios for sub-Saharan Africa with conflicting situations about which areas will get wetter and which will get drier, there is no doubt that the climate change/variability phenomenon is slowly setting in and the general consensus appears to be that southern Africa will experience hotter and drier climatic conditions in the medium to long term (Kinuthia, 1997).This will seriously compromise African agricultural production and access to food, since agricultural land will be lost and there will be shorter growing seasons and lower yields. Consequently, in some countries, yields from rain-fed crops could be halved by 2020 (Oxfam,2007). Sub-Saharan African region will be hit hardest because current information is the poorest, technological change has been the slowest and the domestic economies depend most heavily on agriculture (Mendelson *et al,* 2000; Morton, 2007).

Climate change impact studies, although they are still uncertain on the frequency and severity of adverse weather events, have shown that the effects are significant for low input farming systems, such as subsistence farming that are located in marginal areas and due to socio-economic, demographic, and policy trends have the least capacity to adapt to changing climatic conditions (Slater *et al*., 2007). As result, agricultural activities are by nature prone to risks and uncertainties of various nature including biophysical, abiotic, climatic, environmental, biotic (pests, diseases) and economic (FAO, 2012). Many of these risks have a climatic component and most of them will be affected by climate change, either in intensity, scope or frequency.

1.2. Problem Statement

With the increasing population of about 12 million people in Rwanda and since nearly 90% of the population relies on subsistence agriculture and farmers are dependent on rain for good harvests, food security has become a major concern for the government of Rwanda, thus the agricultural sector has been given a high priority in the government's planning for development.

Though food crops hold a very dominant position in Rwandan agriculture, Rwanda is among the countries with chronic food deficiencies as well as low incomes. It is within this framework that Rwanda joined the rest of the world to commit itself to reduce the malnourished population as stipulated by the commitments made during the World Food Summit held in Rome in 1996.

Agriculture is growing at 5.8% per year and employs 80% of Rwandans of the population and contributes about 33% of GDP and 70% of export revenues (NISR, 2011). Even though it is more important for a big number of citizens and for the country's economy, the agriculture sector in Rwanda is facing many hindrances resulting from climate variability. Therefore, land resource is the most important factor of production and survival for the nation and the entire population, and it will remain the backbone of the national economy for a long time to come. Unfortunately, rapid population growth with 2.6% as shown by the forth population and housing census in 2012 (NISR, 2014) is putting pressure on land which makes it to become more scarce.

Recently, agricultural land is estimated at around 1,380,000 ha, which is about 52% of the country's surface area (MINAGRI, 2012). NISR (2014) has showed that the total Rwandan population in 2012 was 10,515,973 where only 17% was lived in urban areas and 83% in rural areas with small landholdings of only 0.15 ha per rural person. This shows the severity of land scarcity in Rwanda. Consequently, land as a natural resource does not offer many alternatives in terms of arable land elasticity; thus it is exposed to overexploitation. This overexploitation coupled with temperature increase, shift of seasons and low rainfall in drought risk zone like Bugesera accelerates the severity of agriculture vulnerability to climate variability.

Siri*et al*. (2008) point out a testimony of a big threat concerning the aggressiveness and capriciousness of climate variability that Rwanda is experiencing in the region where in the Nile Basin had an increase of about 0.2°C to 0.3°C per decade during the second half of the century, while in Rwanda temperatures increased by 0.7°C to 0.9°C. This will adversely impact on agriculture sector and will result in poor health status and dependence on climate sensitive resources like wetland for instance. Consequently, it requires resilient efforts to ensure agriculture sustainability which is very difficult to achieve.

Regarding to the soil fertility, a high proportion of the Rwandan soils have significant acidity, 75% of the land is "highly degraded," and overall Rwanda has one of the highest negative nutrient balances in sub-Saharan Africa (REMA, 2007). To cope with this problem of acidity and/or soil nutrients deficiency requires liming techniques which neutralize soil acidity and increase activity of soil bacteria. But this is too much expensive so that farmers are not capable to meet all required expenses. Bugesera region is also one of the most regions affected by this problem.

In addition, Bugesera Region has had to live with prolonged and repeated drought since 1998, resulting in food insecurity and massive population movements (REMA, 2007). Although blessed with considerable water resources (lakes and rivers), the region has often recorded frequent famines due to poor harvest in the wake of drought and inadequate water control (Siri, et.al. 2008).

The recent weather consequences Bugesera suffered from include the famine emanating from droughts and high heats of the year 2000 which triggered local people's migrations to other country's regions and the famine (MINIRENA, 2006). In 2004, the food security situation in Bugesera became so dire that the UN World Food Program set up a nutritional centre in 2004 to feed parents and their children numbering more than 40,000.

Also in 2006 high heats and prolonged droughts in Bugesera have occurred and have resulted in famines, water resources drying and tendency of desertification (MINIRENA, 2006). The land was so dry that it could barely produce any crops which lead the community to be poverty stricken and this called for intervention from the government of Rwanda and the USAID to help the community secure food (Hategekimana and Semana, 2013). From this calamity 15 000 persons have registered in need of food relief (PADAB, 2006). The author also states that in 2009, the African Development Bank committed $47 million (estimated Rwf 27billion) in order to improve falling agricultural output and lengthy droughts which affected almost a million people living in Bugesera (Rwanda) and Kirundo (Burundi).

Figure 1: Climate change impacts of planted crops: dryness of crops in 2006

Source: Hategekimana and Semana, 2013

However, if Bugesera continues to experience climate variability related problems, how can farmers will make agriculture more productive? How do farmers from Bugesera will survive? To which sector the country will migrate so as to sustain GDP? To remedy this problem requires more techniques and practices like hillside irrigation; water harvesting and land husbandry works. Unfortunately those techniques are very expensive so that it is difficult for local farmers to afford them and hence agriculture profitability is low. This is aggravated by cumbersome irregularity and insufficiency of rainfall in drought prone areas like Bugesera.

On the other hand agriculture is recognized in the EDPRS1 and EDPRS2 as one of the priority sectors that will both stimulate economic expansion and make the greatest contribution to poverty reduction and food security. However, as demonstrated in the discussion above, a number of factors are threatening these efforts. Even though the Government of Rwanda (GoR) has put in place a number of strategies to address these threats like land husbandry (soil bunds, bench and narrow cut terraces, agro-forestry among others), hillside irrigation and marshland development to name but few, it is very difficult to cover the whole country.

From this perspective a strong resilience is required. This research comes therefore, to analyze the relationships between exposure and sensitivity to climate variability, as well as the potential of adaptive capacity building and coping strategies. Once this is attained, it could be a crucial input in decision making processes regarding where to invest, who should make the investment (government, firms, nonprofits, private citizens, etc.), and where to put more emphasis.

1.3. Objectives, Research Questions and Hypothesis

1.3.1. Main Objective

The main objective of this study is to assess the adaptation to climate variability in Agriculture Sector in Rwanda, especially in Bugesera. The study will focus on grain legumes.

1.3.2. Specific objectives

This study will specifically

1. Assess exposure of grain legumes to climate variability in Bugesera,
2. Investigate the sensitivity of grain legumes' yields to climate variability in Bugesera,
3. Analyze the ability of the farmers in case study to adapt to the effects of exposure and sensitivity.

1.3.3. Research questions

For the objective 1: To assess exposure of grain legumes to climate variability in Bugesera.

- i. What are the climate variability trends in Rwanda since 1970s up to 2014 especially in Bugesera district?
- ii. What is the frequency of climate variables' threshold? Risk or frequency of climate variables higher than fixed value?
- iii. What is the significance of this climate variability especially in Bugesera district?
- iv. Which impacts that grain legumes could be suffering from due to the climate variability in Bugesera district?

For the objective 2: To investigate the sensitivity of grain legumes' yields to climate change in Bugesera

- i. How grain legumes yields have been changed from last years ago in Bugesera district?
- ii. Are the seeds of grain legumes being cultivated in the case study compatible with existing climate conditions in Bugesera district?
- iii. Is there any technology applied to improve seeds that may resist to climate variability? If there is any, how is it efficient in Bugesera district?

For the Objective 3: To analyze the adaptive capacity to mitigate with risks and recover from shocks of smallholder farmers in the study area.

- i. How is the economic wealth of people situated in case study?
- ii. What are the practices do farmers of case study apply in agriculture sector to recover from or adapt with climate variability?
- iii. Which information and skills do local people of Bugesera district have concerning the climate variability and its adaptation?
- iv. What infrastructures being in Bugesera that can sustain agriculture practices?

v. How is the performance of available institutions involved in agriculture sector?
vi. Do available infrastructure, technology and economic wealth equitably distributed?

1.3.4. Research hypothesis

The current study was guided by the following research hypothesis:

The yield of grain legumes in Bugesera is much sensitive to climate variability because the small farmers of Bugesera do not have enough capacity of adaptation to climate change/variability though they have enough awareness and commitment to climate variability mitigations.

1.4. Research Significance, Scope and Case Study Justification

1.4.1. Research significance

Agriculture and food systems are complex: they are biophysical, economic and social (Holmgren, 2012). These dimensions act together at various scales, from local to global, again global to local. This is why to consider adaptation of agricultural and food systems, we need to adopt a holistic approach, from different angles and different perspectives as well as to take into account at the same time diverse perspectives and approaches. It is in this regard that the current study was carried out.

Furthermore, most of researches and/or surveys that are being carried out by the National Institute of Statistics of Rwanda and MINAGRI so far are more concentrated on reporting agriculture results. It could be more important if deep analysis is made by considering farmers' capability to adapt to current climate variability related issues, how agriculture is exposed to climate threats and crop sensitivity.

Nevertheless, Rwandan agriculture is really prone to climate variability. This creates the need to assess thoroughly the level of vulnerability and adaptive capacity to shocks and new changes. This could facilitate to know what is available and what is missing to be addressed in planning processes so as to sustain agriculture, a delicate sector but the most important for more than 90% of the population.

This research is the one of the response for this issue as it aims at assessing the level of adaptation for Bugesera and for other vulnerable places in Rwanda. This will be done by analyzing adaptation indicators including the level of exposure to climate variability, crop sensitivity vis-a-vis climate variability and people's adaptive capacity to climate shocks and to new changes.

1.4.2. Case study Justification

Bugesera district has been selected to be the case study because of three reasons: firstly Bugesera was in the past one of the main food producers for the country but the region has faced chronic food insecurity since 1999 (REMA, 2007); secondly, almost 18% of the Rwandan population is facing severe food insecurity, and Bugesera has been identified as the most affected (NISR, 2011); thirdly, the main factor of food insecurity in Bugesera region is unpredictable and inadequate rainfall, which is linked to prolonged drought while in other areas of the country the main causes have been identified to be land degradation (e.g. low soil fertility and soil erosion). Based on these reasons, Bugesera is a good case study for this research.

1.4.3. Scope of the Research

To a great extent, increasing adaptation can be achieved by reducing vulnerabilities and increasing adaptive capacity (Füssel, 2009). This can be achieved by reducing exposure, reducing sensitivity and increasing adaptive capacity for every type of risk (Holmgren, 2012). This research therefore focused on these indicators in order to achieve main and specific objectives and find answers to the research questions as well as verify hypothesis of this research. The exposure of grain legumes to climate change/variability was analyzed using temperature and rainfall records from Rwanda Meteorological center. For sensitivity analysis the information about the background of crop yield coupled with type of seeds being cultivated in the case study were gathered during household survey. Here I was interested to know how farmers' awareness on crop yields variation from last years ago and what local farmers consider as the reason of this variation, mainly for grain legumes.

CHAPTER TWO: METHODOLOGY

This chapter gives an overview of the study area and emphasizes on required data with associated methods, tools and techniques to collect and to analyze them. At the end due to expert knowledge and information from district agronomist this section indicates the study area delineation.

2.1. Description of the Study area

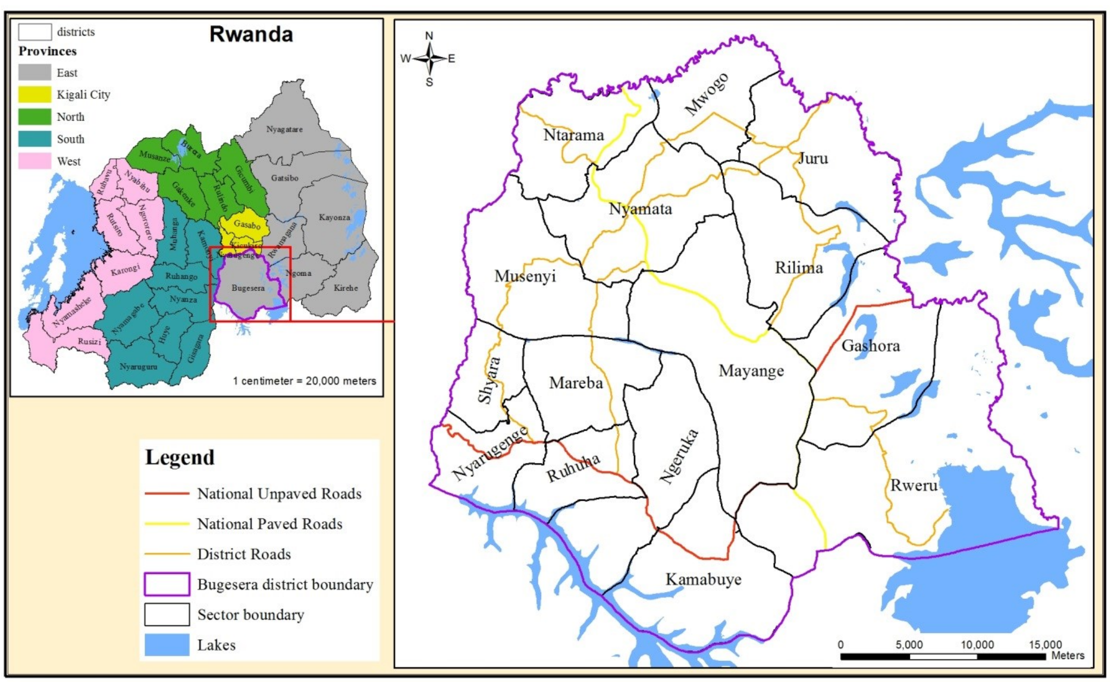
Bugesera district is located in the South West of Eastern Province. It is bordered in the south by Burundi, Ngoma District to the East, and Kigali City and Rwamagana District to the North.

Bugesera's relief has a succession of undulating hills, dry valleys and some marshes due to tectonic collapse. 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: Mount Shyara (1,772 m), Mount Juru (1667 m), Mount Maranyundo (1,614 m) and Mount Mwendo (1575m). The area is prone to droughts, and has a higher average daytime temperature than the Rwandan average, and lower precipitation, which sometimes lead to droughts (CSEA, 2014).Since late 1990, the districthas experienced long periods of drought and low levels of rainfall.

Bugesera had total population of 363,339 by end of 2012 representing 36.2% increase from 2002 when the population was only 266,775 (NISR, 2014). Bugesera is predominantly rural and the main occupation of the population is subsistence agriculture (UNEP, 2011). Most of its population relies on rain-fed agriculture to support their livelihood (FAO, 2009). Like other areas in Rwanda, this zone is bimodal with the long rains falling between February and May, and the short rains falling between September and December. However one out of every two years, the rainfall of the first rainy season is insufficient, resulting in deficit crop production(CSEA, 2014). Households can typically recover from initial losses during the second harvest (CSEA, 2011).

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 arepracticed. The main food crops grown in Bugesera are sorghum, maize, groundnuts, cassava, soy bean, sweet potatoes, beans, and rice (UNEP & UNDP, 2007). However in a bad year, households especially the poor are at risk of food insecurity (USAID, 2011).

Figure 2: Administrative map of Bugesera



Source: Author, 2016

2.2. Methodology

2.2.1. Collection of Secondary Data

2.2.1.1. Desk review

To understand the context of the problem of climate variability and associated mitigation measures, international and national policy documents including literature on the existing policies in the country on climate change adaptation in agriculture sector, extent to which vulnerable people's issues are integrated in broad government policies and programs were consulted and analyzed.

Furthermore, the achievements attained by projects, programmes and NGOs which operated or that are ongoing in Bugesera which would have significant impacts on climate change andvariability mitigation were also consulted.Information extracted from literature review was instrumental to my understanding of impacts of climate variability on agriculture.

2.2.1.2. Acquisition of data on climate variability

To assess the climate variability in the study area, data on temperature and rainfall are essential. Temperature and rainfall records were collected in the form of excel sheet from the Rwanda Meteorological Centre. The Excel-based model MAKESENS was used as the main tool to analyze the variation of temperatures and rainfall since last years ago and thus the focus of data collection was on the format required for this model (Table 1).

Apart from these climate data, I also collected spatial data including administrative boundaries. All of these data helped to analyze the climate variability, its significance and its related impacts on grain legumes productivity in Bugesera district.

Table 1: Datasets used in the study

Types of data	Usage	Source
Rainfall records	Analysis of historical rainfall trends	Rwanda meteorological center
Temperature records	Analysis of historical temperature trends	Rwanda Meteorological Center
Administrative boundaries	Will help in being familiar with the case study	National Institute of Statistics in Rwanda (NISR)

Source: Author, 2016

2.2.2. Primary Data

2.2.2.1. Household survey

A survey was organized with heads of households to captureinformation about trends of crop yields from last years ago, seeds compatibility, household economic capacity, agriculture dependency, physical resources, demographic characteristics, people's awareness and information about climate variability and its adaptation. The survey also aimed at knowing, how local farmers use to choose the seeds to be cultivated and measures/strategies/actions that local farmers are applying to make agricultural practices more performing.

It is within this framework that a structured questionnaire was designed in order: i) to be able to contact large numbers of people quickly, easily and efficiently, ii) to create, code and interpret quickly and easily the questionnaires, and iii) to facilitate questionnaire standardization (for instance every respondent was asked the same question in the same way hence I was sure that everyone in the sample answers exactly the same questions, which makes this a very reliable method of my research)(UoP, 2010).

2.2.2.2. Sampling Techniques

The survey was conducted in all cells of Mareba Sector in Bugesera district. The selection criterion was based on the criticalness of vulnerability of grain legumes to climate variability based on expert knowledge on the case study and information I got from agronomist officer of Bugesera district.

To select the area to be surveyed, I used cluster area sampling techniques. The advantage of using this method is time and cost saving as well as to gain diverse information from different areas of the case study. The clusters that concerned with the survey were represented by the cells of Mareba sector.

As it was impossible to proceed to an enumeration because of insufficiency of time and financial means, sampling was necessary to determine the number of people to be surveyed. The Yamane's formula (1967) wasapplied to determine the sample size as follow:

n**= N/ (1+N (e)^2)**

Where **n** is the sample size, **N** is the population size, and **e** is the level of precision estimated to be 10% or 0.1 and confidential level of 90%.

The sample size in Mareba sector therefore: n **=** $\frac{\mathbf{5767}}{\mathbf{1+5767\ (0.10)^2}} = 98.24 \sim 99$

This means that in Mareba Sector I surveyed 99 households in total.

Table 2: Sampling design for each PSU in Mareba Sector

Sector	Cell	Total Households	Formula	Sample Size
MAREBA	Bushenyi	1,448	$\frac{1448x99}{5767} = 24.8$	25
	Gakomeye	917	$\frac{917x99}{5767} = 15.7$	16
	Nyamigina	828	$\frac{828x99}{5767} = 14.2$	14
	Rango	1,609	$\frac{1609x99}{5767} = 27.6$	28
	Rugarama	965	$\frac{965x99}{5767} = 16.3$	16
Total	5 Cells	5,767		99

Source: Mareba Sector (2016)

Table 2 shows the sample size per each cell considered as Primary Sampling Unit (PSU) calculated by using inverse proportion because the selection probability for each element in a cell (considered as PSU) was set to be proportional to its size measure up to a maximum of 1. While selecting a sample I took into consideration the varying size of each PSU (Cell) within the study area. The sample size was calculated based on the population itself.

2.2.2.3. Interview with key informants

Interview mainly targeted local leaders such as agronomist officer at sector level, Socio-Economic Development Officers at cell level, because they are the ones to follow up agriculture activities and other government programmes implementation. Their views, observations, and experiences with regard to the research problem were sought. Face to face interview was carried out and facilitated me to clarify the number of issues in the questionnaire and to make the results of this study more reliable. The interview focused on local leaders' information/awareness, plans, projects, initiatives and priorities towards the improvement of food security, increasing agriculture productivity as well as the reducing the impacts of climate variability on agriculture.

2.2.2.4. Observations

During the research I used direct observation to collect evaluative information. Observations have been backed up by taking photos(I used digital camera of 12x12 Mega Pixel) and writing down what has been observed in relation to purpose of the study.

2.3. Data Analysis

2.3.1. Data from household Analysis

As this study is both quantitative and qualitative in nature, data collected were edited from time to time for accuracy, completeness, uniformity and consistency. Data were analyzed before, during and after data collection basing on the main study themes. Before the data entry, the written questionnaires have been crosschecked to minimize missing information. After data entry, the data set were checked once more to minimize any mistyping mistake.

During data entry all data were transformed into quantitative by showing the frequency and occurrence, then, they were integrated in SPSS 16.0 within which they have been analyzed. The analysis referred to SPSS 16.0 and was based on Analysis of variance (ANOVA) to assess the significance of differences in means between categories in a variable with regard to sample variation.

2.3.2. Climate Data analysis

The analysis of climate data used the records from Kigali Airport meteorological station which is the closest functioning station, and whose climatic conditions resemble those of the northern parts of Bugesera (REMA, 2007). Ruhuha and Nyamata stations are closer than Kigali airport station but they started functioning in 2007 hence records from these stations couldn't help to assess rainfall and temperature trend for long period. The missing figures for 1994 are due to the fact that no recordings were taken between April and October 1994, as a result of the Genocide against Tutsi at the Kanombe International Airport.

Analysis of the meteorological records was performed using the Excel-based tool 'MAKESENS' (Salmi*et al*., 2002). The software combines two tests; the first is a nonparametric Sen's method for identifying the magnitude of any trend and the second is a nonparametric Mann-Kendall test to identify the significance of any trend (Sen, 1968). In the text, trends in different variables are described with reference to their 'significance'; this is a statistical term that indicates the likelihood of that trend occurring by chance. Where a trend is described as significant it will be followed in brackets by the level of significance (either 0.1, 0.05, 0.01 or 0.001; i.e. the chance of that trend occurring by coincidence would be 10%, 5%, 1% or 0.1% respectively). Where a trend is not significant, it has a better than 10% chance of occurring by coincidence and therefore it cannot be ruled out that it happened by fluke. Where no significant trend is found, a corresponding graph will not have a trend line plotted.

Furthermore, the software detects trends in annual values, so monthly values were either summed or averaged (as appropriate for the variable) to give an annual value. Where seasons are assessed, monthly data were summed or averaged into two rainy seasons for the analysis: Those seasons re March-April-May (MAM) and October-November-December (OND). Three months per season have been chosen because grain legumes (beans, peas and soybeans) have their maturity after 120 days.

It should be noted that as all the data are monthly rather than daily, it was not possible to ascertain information on changes in heavy rainfall events or the specific timing of the start and end of the rainy seasons (though it is possible to assess changes in seasonal totals with the monthly data available).

CHAPTER THREE: CONCEPTUAL FRAMEWORK

Agricultural production is submitted to risks of various types such as political instability, economic and price-related risks, climatic, environmental, pests and diseases, at different scales (Fellmann, 2012). Climate variability affects the agriculture sector through increased variability with regard to temperature, rain, frequency and intensity of extreme weather events, changes in rain patterns and in water availability.

One way to cope with these challenges comprised by climate change is to build a resilient adaptation in the agriculture sector. To perform this, requires improving adaptive capacity to cope with shocks, mitigate with new changes and reducing vulnerability to climate variability (Futuyama, 1979). Reducing vulnerability requires decreasing potential impacts resulting from exposure and sensitivity to climate variability and change (Lavell*et al*., 2012).

This section aims at articulating the broad concepts namely adaptation, vulnerability and risks within the context of climate variability in such a way that they can be of use to frame an approach applicable to concrete issues in the agricultural systems.

3.1. Adaptation

3.1.1. Definition

The term adaptation, as it is presently used in the global change field, has its origins in natural sciences, particularly evolutionary biology and it broadly refers to the development of genetic or behavioral characteristics which enable organisms or systems to cope with environmental changes in order to survive and reproduce (Futuyama, 1979; Winterhalder, 1980). O'Brien and Holland (1992) define the process of adaptation as one by which people add new and improved methods of coping with the environment to their cultural repertoire. Denevan (1983) considers (cultural) adaptation as a process of change in response to a change in the physical environment or a change in internal stimuli, such as demography, economics and organization, thereby broadening the range of stresses to which human systems adapt beyond biophysical stress.

Based on the ideas got from these aforementioned notions, adaptation can be seen as adjustment, practical steps, process and outcome. Therefore adaptation is:

i) **Adjustment** in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities (IPCC, 2007).

ii) **Practicalsteps** to protect countries and communities from the likely disruption and damages which will result from effects of climate change (Harley, et.al, 2008). For instance the practices performed by farmers to lessen and/or mitigate with climate related impacts on agriculture such as hillside irrigation, planting seeds resisting to weather conditions among others.

iii) **Process** by which strategies to moderate, cope with and take advantage of the consequences of climatic events are enhanced, developed, and implemented (UNDP, 2005)

iv) **Outcome** of a process that leads to a reduction in harm or risk of harm, or realization of benefits associated with climate variability and climate change (UKCIP, 2003).

Adaptation as process is an open-ended term lacking time or subject references while adaptation as an outcome is likely to have more tangible results than adaptation as a process (Harley, 2008). Note that these varied interpretations have implications for monitoring and evaluating outcomes and developing adaptation indicators.

From this definition it is clear that building strong adaptation requires: well organized human systems (such as information and technology sharing, sustainable policies, institutional capacity to name but few), infrastructure, programmes and plans set for climate change/variability mitigation as well as efficient implementation framework in order to achieve tangible outputs effectively.

3.1.2. Building adaptive capacity

According to (Winterhalder, 1980), determinants of adaptive capacity have been widely debated in the literature and include the following:

- The range of available technological options for adaptation.
- The availability of resources and their distribution across the population.
- The structure of critical institutions, the derivative allocation of decision-making authority, and the decision criteria that would be employed.
- The stock of human capital, including education and personal security.
- The stock of social capital, including the definition of property rights.
- The system's access to risk-spreading processes (e.g. insurance).
- The ability of decision-makers to manage information, the processes by which they determine
- Which information is credible and the credibility of the decision-makers themselves.
- The public's perceived attribution of the source of stress and the significance of exposure to its local manifestations.

However, according to IPCC (2007) building **adaptive capacity** is seen as the ability (or potential) of a system to adjust successfully to climate change (including climate variability and extremes) to: (i) to moderate potential damages; (ii) to take advantage of opportunities; and/or (iii) to cope with the consequences.

Generally speaking, adaptive capacity to climate change depends on physical resources, access to technology and information, varieties of infrastructure, institutional capability, and the distribution of resources (Tubiello and Rosenzweig, 2008). Indicators for adaptive capacity compose economic capability, physical infrastructure, social capital and institutional capacity. Economic capability represents the economic resources available to reduce climate change vulnerability. It includes human resources and technological alternatives (Yohe and Tol, 2002). Physical infrastructure describes the hardware available to enhance adaptive capacity, while indicators of social capital include social network of individual know-how and mutual trust to cope with climate impact(Futuyama, 1979). Institutional capability is represented by the political leadership and governance structure, disaster prevention systems, and climate change policy (O'Brien and Holland, 1992). For example, systems of local food supply and distribution, early warning systems, accessibility of relevant information, and availability of crisis management programs and policy (McCarthy et al., 2001) are part of adaptive capacity. Communities must build their resilience, including adopting appropriate technologies while making the most of traditional knowledge, and diversifying their livelihoods to cope with current and future climate stress (Cutter *et al.,* 2000).

The choice of adaptation interventions depends on national circumstances. Thus, to enable workable and effective adaptation measures, ministries and governments, as well as institutions and non-government organizations, must consider integrating climate change in their planning and budgeting in all levels of decision making.Adaptation measures in one sector will involve a strengthening of the policy that already exists, emphasizing the importance of including long term climate change considerations along with existing local coping mechanisms and integrating them into national development plans. Multi-sectoral adaptation options relate to the management of natural resources which span sectors, for example, integrated management of water.

Cross-sectoral measures also span several sectors and can include: improvements to systematic observation and communication systems; science, research and development and technological innovations such as the development of drought-resistant crop varieties or new technologies to combat saltwater intrusion; education and training to help build capacity among stakeholders; public awareness campaigns to improve stakeholder and public understanding on climate change and adaptation; strengthening or making changes in the fiscal sector such as new insurance options; and risk/ disaster management measures such as emergency plans (IPCC, 2007).

3.2. Fundamental Concepts in Adaptation

3.2.1. Climate impacts, vulnerability and risk

Climate impacts, vulnerability and risk are distinct but related concepts. Impacts may be beneficial or harmful, with most observations and projections showing a range of effects on the environment, economy and society (IPCC, 2007) The vulnerability of a system is defined as the degree to which it is susceptible to and unable to cope with the adverse effects of climate change, including climate variability and extremes (Denevan, 1983). It is a function of the character, magnitude and rate of change and variables to which the system is exposed, its sensitivity, and its adaptive capacity (Folke, et.al. 2002). Sensitivity relates to the degree to which a system could be affected, either adversely or beneficially, by climate-related stimuli (Adger*et al*., 2007). Adaptive capacity is the ability of a system to adjust to climate change, to moderate potential damage, to take advantage of opportunities, or to cope with consequences (Harley, et.al, 2008). The concept of risk is often confused with vulnerability. Risk relates to a characteristic of a system or a decision where the probability that certain states or outcomes have occurred or may occur is precisely known (Smit*et.al*., 1999). Risk assessments combine the probability of an event occurring, with the impact or consequence associated with that event (UNFCCC, 2007).

3.2.1.1. Climate Impacts

In agriculture sector, climate variability and change is one of cumbersome issues which influence farmers' adaptation to climate impacts. Some of the climate impacts are directs (e.g., reduced water availability due to increased demand from others), some will be due to extreme weather events (e.g., stronger storms) while others will be due to incremental climatic changes such as rising ambient air temperatures (Gardiner and Associate, 2011). Table 3 summarizes some of the relevant physical climate impacts and value chain risks (and, in some instances, opportunities) for agriculture sector.

Table 3: Climate Impacts and value chain for agriculture sector

RELEVANT SHORT- AND LONG-TERM PHYSICAL CLIMATE IMPACTS	ILLUSTRATIVE EFFECTS ON VALUE CHAIN
• Water scarcity and droughts • Increased frequency and severity of droughts • Changing rainfall patterns and decreased rainfall intensity • Increased weather extremes and variability • Rising average temperatures • Shifts in seasons • Changes in pest and disease distribution and prevalence • Loss of biodiversity	• Decreased crop yield and potential crop failures • Loss of productive land (e.g., due to increased soil salinity) • Altered growing conditions and seasons • Increased exposure to pests and diseases • Increased irrigation demand and costs • Commodity price volatility • Distribution network problems • Disruptions to farmers and labor force • Water conflicts with communities and other users (and damaged corporate reputation)

Source: Gardiner and Associate, 2011

Table 3 shows that climate variability andclimated change disturb the agricultural ecosystem, resulting in the change in agricultural climatic elements such as temperature, precipitation, and sunlight, while further influencing the arable, livestock, and hydrology sectors (Folke, 2006). Adaptation measures that can sustain the resilience towards physical climate impacts include the application of land husbandry technologies (such as for instance terracing, agro-forestry,

liming and afforestation), water harvesting and irrigation (both hillside and marshland irrigation). Unfortunately, these practices are expansive so that developing countries like Rwanda cannot afford it at large scale.
However, there is a growing consensus in academic literature which argues that greater attention needs to be focused on investigating the other critical aspect of climate adaptation, which is the capacity for social-ecological systems to renew, develop and to utilize disturbances as opportunities for innovation and evolution of new pathways that improve the system's ability to adapt to macroscopic changes (Tompkins, Emma and Adger, 2004).

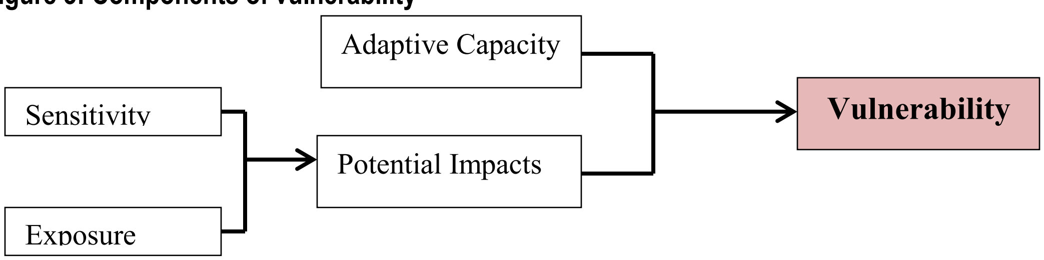
3.2.2.Vulnerability

According to IPCC (2007) vulnerability to climate variability is the degree to which a system is susceptible to, and unable to cope with adverse effects of climate variability including climate extremes. Vulnerability is then a function of the character, magnitude, and rate of climate change and variation to which a system or community is exposed, its sensitivity, and its adaptive capacity (Smit&Wandel, 2006). Thus, agricultural vulnerability to climate change can, for example, be described in terms of exposure to elevated temperatures, the sensitivity of crop yields to the elevated temperature and the ability of the farmers to adapt to the effects of this exposure and sensitivity by, for example, planting crop varieties that are more heat-resistant or moving to another type of crop.

IPCC's definition of vulnerability (2007) specifically highlights three components of vulnerability in the climate change context that are exposure, sensitivity and adaptive capacity (see the figure 3). It implies that a system is vulnerable if it is exposed and sensitive to the effects of climate variability and at the same time has only limited capacity to adapt (Smit*et al*., 1999; Smit and Wandel, 2006).

In the climate change context, **exposure** relates to the nature and degree to which a system is exposed to significant climatic variations (IPCC, 2001). The exposure can be present or future. The present exposure refers to the susceptibility of being affected by the present climate settings (For instance crops are exposed to the lack of rain). On the other hand, future exposure refers to the predisposition of being disturbed in the future by changing conditions of particular factors.

Figure 3: Components of vulnerability



Source: IPCC, 2001

However, climate change can alter and increase the future exposure whereas current people's behaviors increase or lessen the level of exposure (Lavell et al., 2012). Climate exposure indicators may include biophysical factors such as temperature rise, heavy rain, drought, and sea level rise (IDB, 2013).

The **sensitivity** of agriculture to climate change and/or variability reflects the degree to which agriculture is affected, either negatively or beneficially, by climate variability or change (Adger et al., 2007). It is therefore the responsiveness of crops to climatic influences, and the degree to which changes in climate might affect it in its current form (IPCC, 2007).

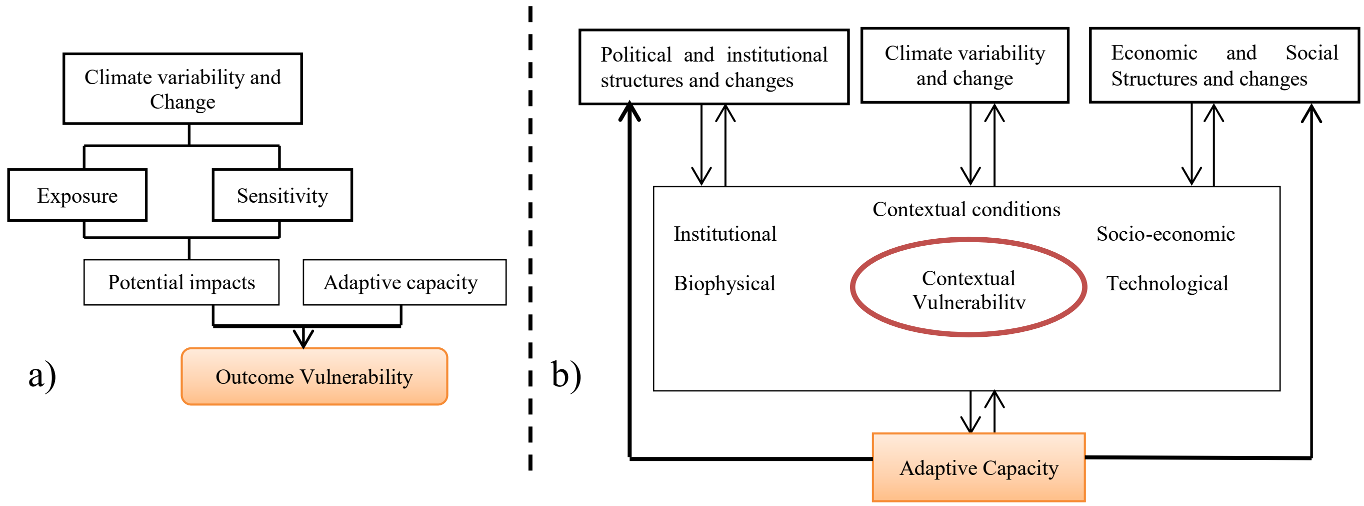
Indicators of sensitivity can encompass geographical conditions, land use, demographic characteristics, and industrial structure such as dependency on agriculture and extent of industrial diversification (IDB, 2013).

Exposure and **sensitivity** together describe the potential impacts that climate change can have on agriculture system. However, it has to be noted that even though a system may be considered as being highly exposed and/or sensitive to climate change/variability, it does not necessarily mean that it is vulnerable (Gallopin, 2006). This is because neither exposure nor sensitivity account for the capacity of a system to adapt to climate change (i.e. its adaptive capacity), whereas vulnerability is the net impacts that remains after adaptation is taken into account (Fellmann, 2012). Thus, the adaptive capacity of a system affects its vulnerability to climate change by modulating exposure and sensitivity (Yohe and Tol, 2002).

3.2.3. Concepts and Interpretations of Vulnerability

Two of the most prominent vulnerability concepts in the context of climate change are outcome and contextual vulnerability, which differ mainly owing to their interpretation of vulnerability as being the end-point or the starting point of the analysis. Both concepts are graphically represented in the figure 4

Figure 4: Frameworks depicting two interpretations of vulnerability to climate change



a. Outcome vulnerability; **b. contextual vulnerability**

Source: Williamson, Hessen and Johnston, 2012

3.2.3.1. Outcome vulnerability

Outcome vulnerability is a concept that considers vulnerability as the potential net impacts of climate change on a specific exposure unit after feasible adaptations are taken into account (Williamson, Hessen and Johnston, 2012). However, regarding the adaptive capacity, most emphasis is given to biophysical components and the role of socio-economic components in modifying the effects of climate change (Tubiello and Rosenzweig, 2008). For that reason, the most vulnerable systems are considered to be those that will experience the most dramatic physical changes (Peltonen-Sainio, 2012).

Vulnerability of agricultural yields to climate variability in the future tend to follow an outcome vulnerability approach and typical technological solutions for adaptation in the agricultural sector include for example the use of different crop seeds, production techniques or water management (Challinoret al., 2009)

Outcome vulnerability approaches are also often associated with questions such as: what are the expected net impacts of climate change in different regions? Or which sector is more vulnerable to climate change and variability? However, answering these questions may also form an important part of contextual approaches, especially if the economy of a society is dominated by activities that are sensitive to climate change and variability (Fellmann, 2012).

3.2.3.2. Contextual vulnerability

Contextual vulnerability is a concept that considers vulnerability as the present inability of a system to cope with changing climate conditions, whereby vulnerability is seen to be influenced by changing biophysical conditions as well as dynamic social, economic, political, institutional and technological structures and processes (Adger, 2006).

Contextual vulnerability approaches typically focus more on the current socio-economic determinants or drivers of vulnerability, i.e. social, economic and institutional conditions. Specific determinants that can increase or decrease a system's vulnerability include, for example, marginalization, inequity, food and resource entitlements, presence and strength of institutions, economics and politics (Adger and Kelly, 1999; O'Brien and Leichenko, 2000; O'Brien *et al.,* 2004; Cardona *et al.,* 2012). Thus the contextual interpretation of vulnerability explicitly recognizes that vulnerability to climate change is not only a result of biophysical events alone but is also influenced by the contextual socio-economic conditions in which climate change occurs (O'Brien *et al.,* 2007).

Table 4: Difference between two alternative concepts and interpretations of vulnerability in climate change research

	Outcome vulnerability (end-point interpretation)	**Contextual vulnerability (starting-point interpretation)**
Root problem	Climate change and variability	Socio-economic vulnerability
System of interest	Biophysical, closed or at least welldefined systems	Human security or livelihood interrogation
Starting point of analysis	Scenarios of future climate change	Current vulnerability to climatic stimuli
Vulnerability and adaptive capacity	Adaptive capacity determines vulnerability	Vulnerability determines adaptive capacity
Reference for adaptive capacity	Adaptation to future climate change	Adaptation to current climate variability
Meaning of vulnerability	Expected net damage for a given level of global climate change	Susceptibility to climate change and variability as determined by socioeconomic factors
Illustrative research question	What are the expected net impacts of climate change in different regions?	Why are some groups more affected by climatic hazards than others? Who is vulnerable to climate change and why?
Focus of results	Technologically focused on adaptation and mitigation strategies	Socially focused on increasing adaptive capacity, exploring alternative development pathways, addressing power or equity issues and constraints to respond
Approach used to inform adaptation policy	Top-down approach	Bottom-up approach
Spatial domain	Global to local	Local to regional
Time dimension	Future vulnerability	Current vulnerability

Source: Füssel (2007) and Pearson *et al.*(2008).

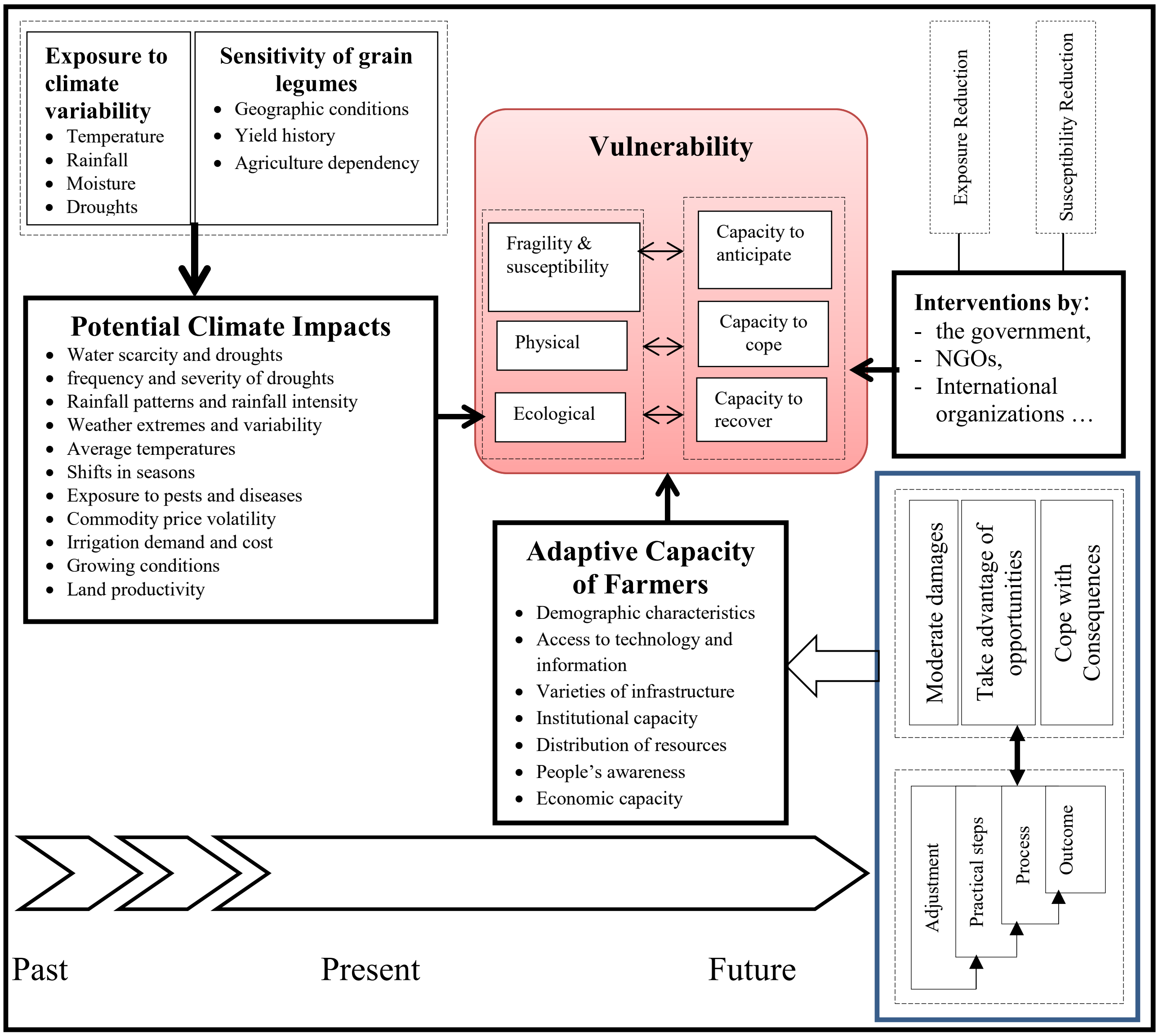
3.3. Conceptual Framework of the Research

Adaptation to climate variability or change is considered as responses to risks associated with the interaction of environmental hazards and human vulnerability or adaptive capacity (Smit&Wandel, 2006). In order to analyze the adaptation to climate variability it is important to understand the obvious climate related impacts, level of vulnerability and adaptive capacity that the community has to lessen climate impacts.

Adaptive capacity is determined by how the community is capable to cope with consequences, take advantage of opportunities and moderate damages in relation to the process. The indicators for adaptive capacity are demographic characteristics, access to technology and information, infrastructure availability, institutional capacity, people's awareness and economic capacity. Adjustment, principal steps, process, outcome are the procedures used to assess the performance of practical steps undertaken to minimize the impacts of climate variability or change.

The climate impacts are the results of exposure of agriculture to climate change or variability and the sensitivity of grain legumes towards the climate change/variability impacts. Furthermore, it is very important to assess the intervention of the government or NGOs in reducing exposure and susceptibility. The intervention can be measured based on plans, programmes and policies or regulations set to protect environment or to lessen level of vulnerability to climate change.Here below is a flowchart illustrating the proposed indicators for this research. Note that those indicators are centered to outcome vulnerability and contextual vulnerability.

Figure 5: Adapted Conceptual Framework for the Research



Source: Author, 2016

CHAPTER FOUR: FINDINGS AND DISCUSSION

This section attempts to respond the research objectives and related questions by analyzing both collected primary and secondary data using the identified methods and techniques.Socio-economic aspects, exposure of grain legumes to climate variability, Adaptive capacity, government policies implications, climate impacts and vulnerability were analyzed and discussed.

4.1. Socio-economic aspects

4.1.1. Demographic characteristics

Among the interviewed people 56 (57%) are women while 43 (43%) are men. According to the marital status of head of families, 17 are single (13 males and 4 females), 50 are married (30 males and 20 females), 25 are widowed (all are females) and 7 divorced (all are females). This situation predicts economic vulnerability at household level for the female headed families where 33.3% of all households are female and widowed/divorced families (This issue of economic vulnerability will be discussed in the following sections).

The mean household size in Mareba Sector is around 4. This number reflected a normal case at country level since most common household sizes in Rwanda vary between three and five individuals (about 51%) per household according to the 4th Rwandan Housing and population census and the mean household size in Rwanda is around 4 individuals (NISR, 2014).

4.1.2. Education level

The households that were covered by survey (99) have got 423 individuals. Among them 187 (44.2%) are adults and would have been supposed to have achieved at least primary studies. As indicated by the table 5most of individuals living in surveyed households have enrolled primary at 57.2% (107), 43 (23%) have not attended school, 27 (14.4%) completed secondary school and 10 (5.4%) have got Bachelor's degree.

Table 5: The Statistics on education level in Mareba Sector

Level of education	No education	Primary	Secondary	Bachelor
Sum	43	107	27	10
Percentage	23%	57.2%	14.4%	5.4%

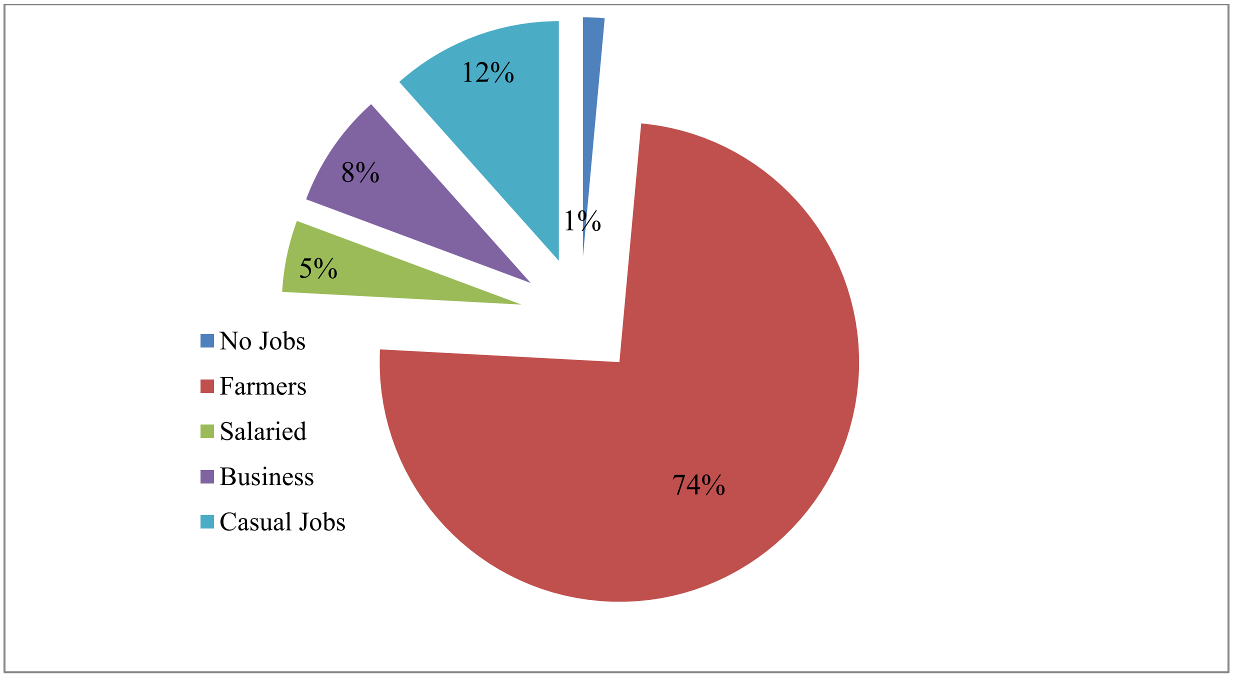
Sourc**e: Author, 2016**

From table 5 this study revealed that the majority (80.2%) of the respondents had not gone beyond primary school level of education.This has serious implications for the level of awareness about climate change and also for the development of indigenous farm practices for adaptation. Education plays an important role in creating awareness in farming communities because educated people are better equipped to source of information (Idrisa, *et.al*, 2012). A minimum threshold in terms of educational qualification is necessary for understanding the scientific and technical nature of modern agriculture(Bamire*et al*., 2002). Education also helps farmers understand where to access farm inputs, how to use them as well as to adjust quickly to disequilibria (Asfaw and Admassie, 2004). Earlier study of(Idrisa, et.al, 2012) reported that education affects agricultural productivity by increasing the ability of farmers to produce more output from given resources and by enhancing the capacity of farmers to obtain and analyze information.

4.1.3. Economy

The surveyindicates that the average total monthly income in Mareba Sector is 4,508Rwf per household (or 150Rwf per day per household). Like other rural areas of Rwanda the economy of Mareba sector is mostly based on agriculture where 74.4% of active population relies on farming activities predominated by agriculture. Other source of income found in the survey includes casual jobs (11.5%), business activities(7.7%), and salaried job (4.8%) while 1.4% is jobless.

Figure 6: Job status in Mareba Sector for adult people



Source: Author, 2016

As most of the farmers rely on agriculture production, much efforts and investments should be oriented in farming activities by all means with the aim of increasingagriculture productivity and mitigate with climate variability and change impacts. Unfortunately, large number of households uses income to purchase food (44.4%) and/or to access other basic needs such as education (10.1%) and health services (9.1%).

Table 6: Priority Areas for Monthly Income Investments in Mareba Sector

Id	Sector of investment	Frequency	Percent
1	Food	44	44.4%
2	Off-farm activities	28	28.3%
3	Education	10	10.1%
4	Health issues	9	9.1%
5	Agriculture	8	8.1%

Source: Author, 2016

Table 6reveals how farmers are not willing to invest in agriculture activities. Therefore, few farmers invest in improving activities because: i) the income is very low, ii) weather conditions are uncertain due to unpredictable and inadequate rainfall which is linked to prolonged drought (Mutabazi, 2010) thus farmers use to experience poor harvest, and iii) Priority is given to other needs that call for money that are pressing and cannotbe deferred such education and health. But farming people still content whatever they harvest.

What's more, the economic capacity for women headed families is lower than men headed families. In female and widowed/divorced families the average monthly income is 3,843.75Rwf over 19,232.3Rwf which is the average monthly income in study area. In addition, the survey indicates neither divorced nor widowed families earn more than 6,000Rwf per month (Table 7).

Table 7: Household income in comparison with men or women headed families

Head of families		N° of HH	N° of HH members	HH average	Income/Month/HH	Income/ HH/Day
Females	Single	4	12	3	17,917	597
	Married	20	103	5	2,117	71
	Widowed	25	106	4	972	32
	Divorced	7	25	4	920	31
Males	Single	13	28	2	4,821	161
	Married	30	149	5	3,812	127
	Widowed	-	-	-	-	-
	Divorced	-	-	-	-	-
General		**99**	**423**	**4**	**4,508**	**150**

Source: Author, 2016

Table7indicates that all of the residents of the case study are under poverty line since they are not ableto earn at least USD 1 (around 770Rwf) per day per person. The cumbersome situation is seen for the female married, widowed and divorced headed families.

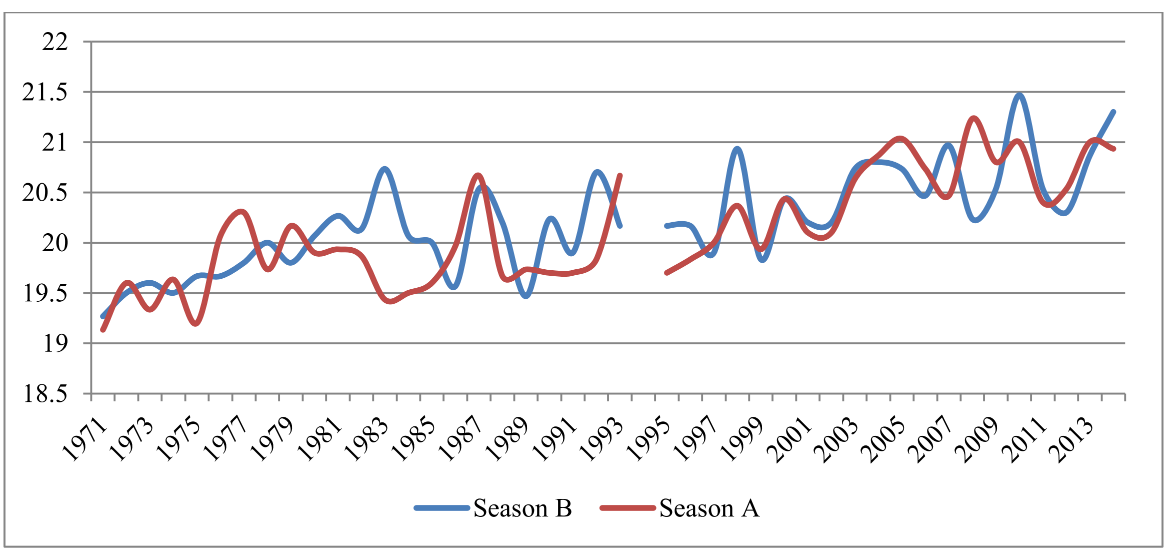
The outlier observed for single female headed families is due to the interviewed household accommodating three nurses.

4.2. Exposure of grain legumes to climate variability in Bugesera

4.2.1. Temperature Dynamics

Mean temperature between 1971 and 2014 to both seasons shows a significant increase (0.001) of 0.39°C and 0.46°C per decade for season A and Season B respectively. This trend is more rapid in comparison to the global observed average reported in the most recent IPCC report (between 0.19°C and 0.32°C per decade for 1979-2005) (Trenberth et al., 2007). Likewise, the trend is not different from the national trend (Rwanda) observed by (McSweeney, 2010) for average annual temperature from 1971 up to 2010 where he observed Mean temperature showing a significant increase (0.001) of almost half a degree per decade (0.47°C).

Figure 7: Season A and B mean annual trend in average temperature for Kigali Airport station (1971-2014)

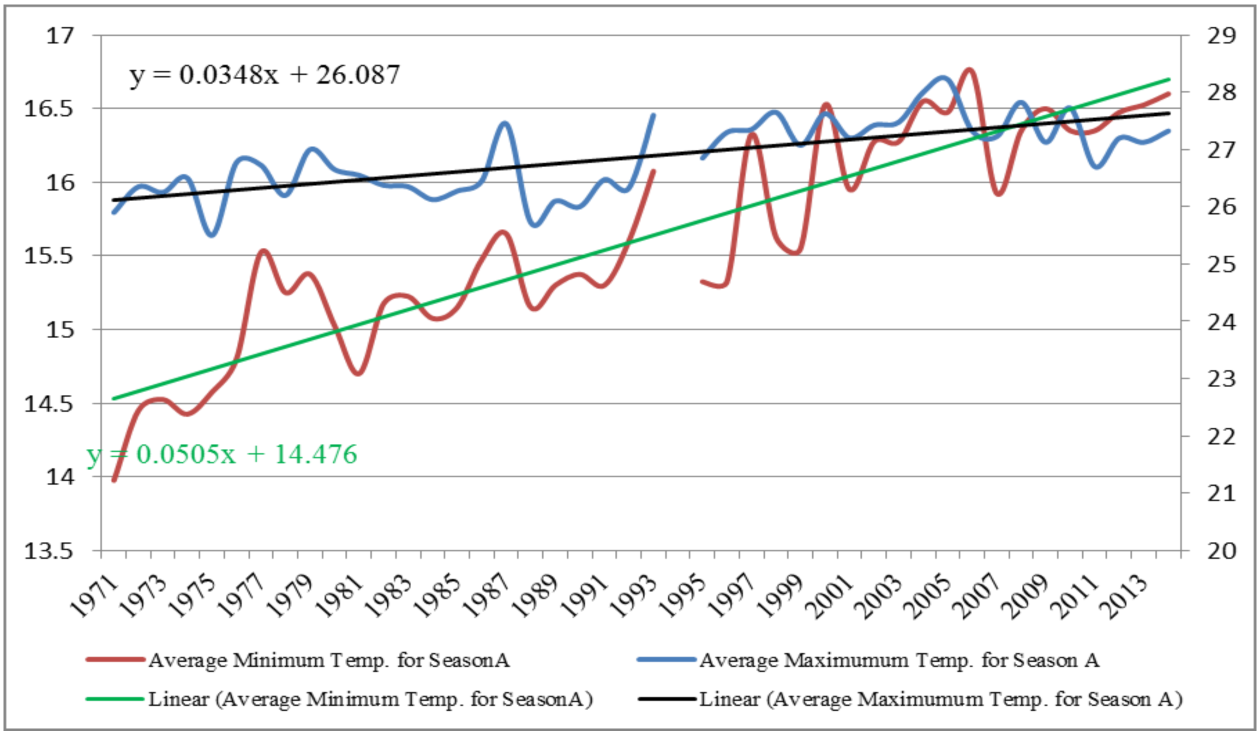


Source: RMC, 2014

In addition, the records for maximum and minimum temperature showed a significant (0.001) increase of around half a degree per decade. The season A has experienced the increase of 0.41°C and 0.50°C for maximum and minimum temperatures respectively while the increase of minimum and maximum temperatures for season B was 0.48°C and 0.46°C respectively. As with mean temperature, these are larger increasing trends than the global observed average, which for both maximum and minimum temperature is 0.29°C per decade over 1979-2005 (Trenberth et al., 2007). Like observations made by (REMA, 2011) on analysis of historical temperatures at Kigali airport station from 1971 to 2010 this research revealed that minimum temperatures are experiencing larger increase than maximum temperatures resulting in reduction in Diurnal Temperature Range (DTR).The national trend over 1971-2010 for minimum temperature also was larger than that of maximum temperature (0.52°C and 0.45°Crespectively), with a corresponding reduction in DTR (McSweeney, 2010).

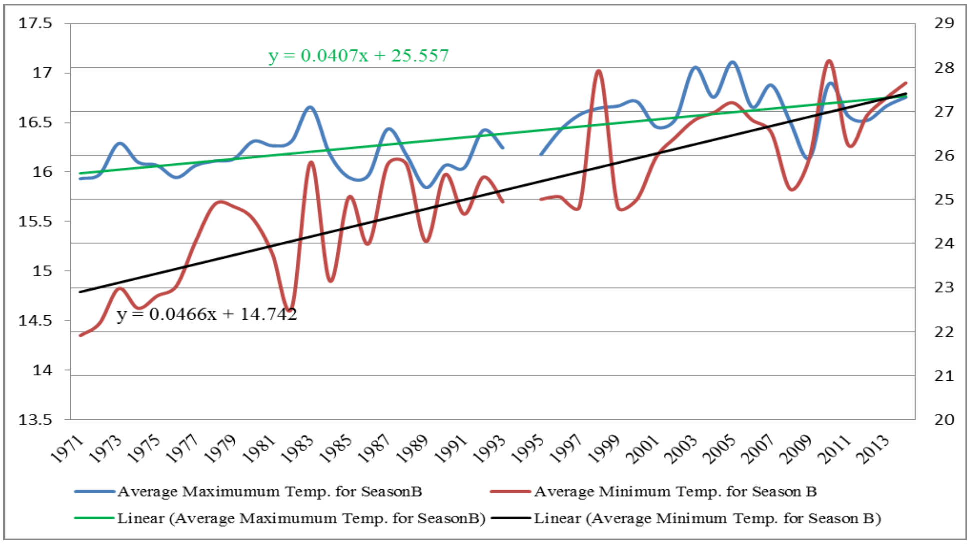
This reduction of DTR offers negative impacts on plant development like decrease in internode length, as well as the small decrease in height, stem thickness and leaf area, could add up to a large decrease in photosynthetic area (Phommy*et.al* 2014).

Figure 8: Annual trend in minimum temperature (left-hand axis) and maximum temperature (right-handed axis) for season A: 1971-2014



Source: RMC, 2014

Figure 9: Annual trend in minimum temperature (left-hand axis) and maximum temperature (right-handed axis) for season B: 1971-2014



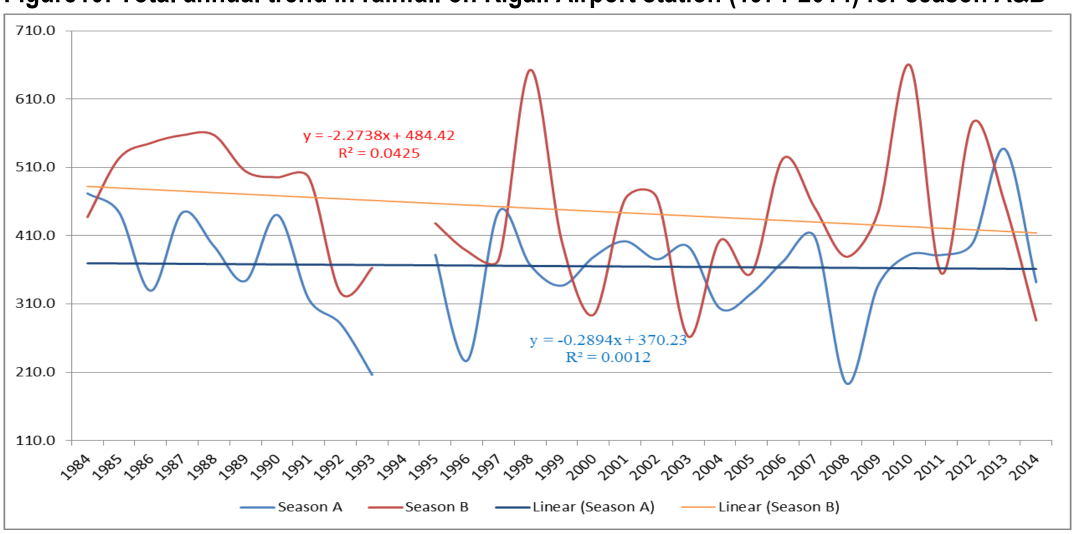
Source: RMC, 2014

Based on the sharp decrease of DTR in the study area grain legumes much exposed to climate change and variability impacts and if no action is taken the farmers will continue to experience poor harvest and/low agriculture profitability.

4.2.2. Rainfall dynamics

Rainfall shows a slight decrease over the period of 1971-2014 which is not significant. Though there are years where rainfall is unusually low or high (See figure 10). The rainfall trend decreases by 4.4mm and 2mm per decade for Season B and Season A respectively.

Figure10: Total annual trend in rainfall on Kigali Airport station (1971-2014) for season A&B

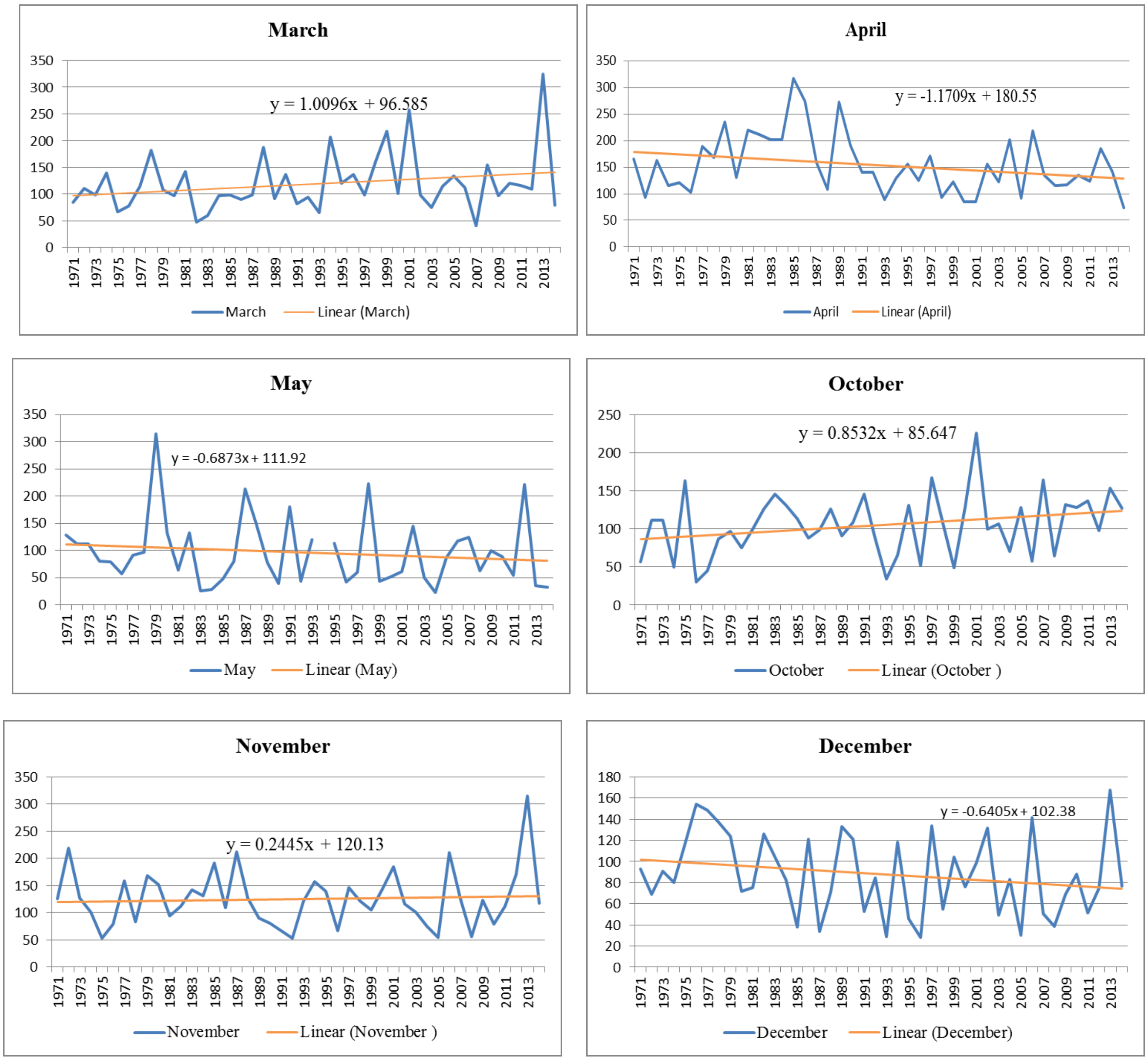


Source: RMC, 2014

Though I didn't found daily climate data to be able to calculate and analyze the frequency of rain days I used information got from REMA (2011). From this perspective, REMA (2011) revealed that annual average total number of rain days has reduced from 148 days in 1971 to 124 days in 2009. These data indicate not only reduction rainy season period, but also increasingly poor distribution and reliability of rainfall with negative impact on agricultural productivity since crops require adequate amounts of soil water within the growing season.

Another focus was made to the trend of rainfall for every month during the rainy seasons. The figure 11 shows that surely, the Season B is becoming worse that season A. The precipitations are decreasing considerably in April, slightly in May and increasing slowly in March. This trend predicts how the yield of grain legumes (beans, peas and soybeans) may decrease in Season B because the flowering and the development of snows occur mainly in April. According to the season A, the quantity of rainfall is generally increasing slightly. It is only in December where the trend is negative with small decrease.

Figure 11: Trend dynamics for rainfall per each month of season A and B.



Source: RMC, 2014

4.2.3. Exposure of grain legumes to climate variability

Reference was made to (OSA, 2007, Myres*et.al*. 2014; Franklin, 1998; Chad, 2012,; Franklin, 1998; and OSA, 2007) to analyze the exposure of grain legumes to climate variability. Those authors showed threshold of the optimum conditions for the development of grain legumes (beans, peas and soybeans).

4.2.3.1. Exposure of grain legumes to temperature variability

According to the temperature conditions, during whole season peas grow reasonably well between 10°C and 30°C with an optimum of 20°C (OSA, 2007), common beans grow within a range of temperatures of 21°C -27°C (Myres*et.al*., 2014) and for soybeans, temperature below 21°C and above 32°C can reduce flowering and pod set (Franklin, 1998).

The results showed that so far temperatures are favorable for beans development but unfavorable for peas and soybeans in both seasons A and B (see table 8 and 9).

Table 8: Temperature per decade for season B (MAM) from 1970s

Decade	Av. Min Temp Season B (°C)	Av. Max Temp Season B (°C)	Mean B (°C)	Resistance status		
				Beans	Peas	Soybeans
1970s	15.0	25.9	19.7	Favorable	Favorable	Not favorable
1980s	15.6	26.0	20.1	Favorable	Not favorable	Not favorable
1990s	15.8	26.7	20.2	Favorable	Not favorable	Not favorable
2000s	16.4	27.2	20.7	Favorable	Not favorable	Not favorable
2010s	16.5	27.1	20.8	Favorable	Not favorable	Not favorable

Source: RMC, 2014

Table 9: Temperature dynamics per decade for season A (OND) from 1970s

Decade	Av. Min Temp Season A (°C)	Av. Max Temp Season A (°C)	Mean A (°C)	Resistance status		
				Beans	Peas	Soybeans
1970s	14.8	26.4	19.9	Favorable	Favorable	Not favorable
1980s	15.3	26.3	20.1	Favorable	Not favorable	Not favorable
1990s	15.8	27.2	20.4	Favorable	Not favorable	Not favorable
2000s	16.4	27.5	21.0	Favorable	Not favorable	Favorable
2010s	16.5	27.2	20.3	Favorable	Not favorable	Not favorable

Source: Author, 2016

	Favorable		Not favorable

Source: RMC, 2014

4.2.3.2. Exposure of grain legumes to rainfall variability

A minimum of 400 to 500 mm rainfall per cropping season (about three months) is required for growing peas and soybean without supplementary irrigation (Chad, 2012 and Franklin, 1998). Beans require a moderate well-distributed rainfall (300-400 mm per crop cycle) but dry weather during harvest is essential (OSA, 2007).

As illustrated by the table10 and 11 the rainfall is becoming insufficient from 2000s in study area so that grain legumes are exposed droughts.

Table10: Rainfall dynamics per decade for season A from 1970s

Decade	Precipitations (mm)	**Resistance status**		
		Beans	**Peas**	**Soybeans**
1970s	313.5			
1980s	332.1			
1990s	302.8			
2000s	287.7			
2010s	433.4			

Source: RMC, 2014

Table 11: Rainfall dynamics per decade for season B from 1970s

Decade	Precipitations (mm)	**Resistance status**		
		Beans	**Peas**	**Soybeans**
1970s	381.3			
1980s	404.3			
1990s	302.8			
2000s	287.7			
2010s	400.9			

Source: RMC, 2014

	Favorable		**Not favorable**

The rainfalls are becoming insufficient to satisfy the development of grain legumes (Beans, peas and soybeans). However, as the rainfalls play the important role in the development of crops, this situation could affect negatively the productivity from agriculture of grain legumes.

Furthermore, it is clear that peas and soybeans could not resist to climatic conditions. This could be true because local farmers have confirmed that beans are the most cultivated crop in the case study with 98% and peas and soybeans are among the crops that are becoming rare at 97% and 93% respectively.

4.2.4.Sensitivity of grain legumes to climate variability in Bugesera

I identified all of the data express changes in yields of all grain legumes (beans, peas and soybeans) for all seasons since all R square are above 70%. For the whole model, the ANOVA significances are below 5% so that the model is significantly predicted. About the coefficients, t-values are also below 5% hence the dependent variables (temperature and rainfall) are statistically significant to predict the change in yield.

Table 12: Yield Model Characteristics

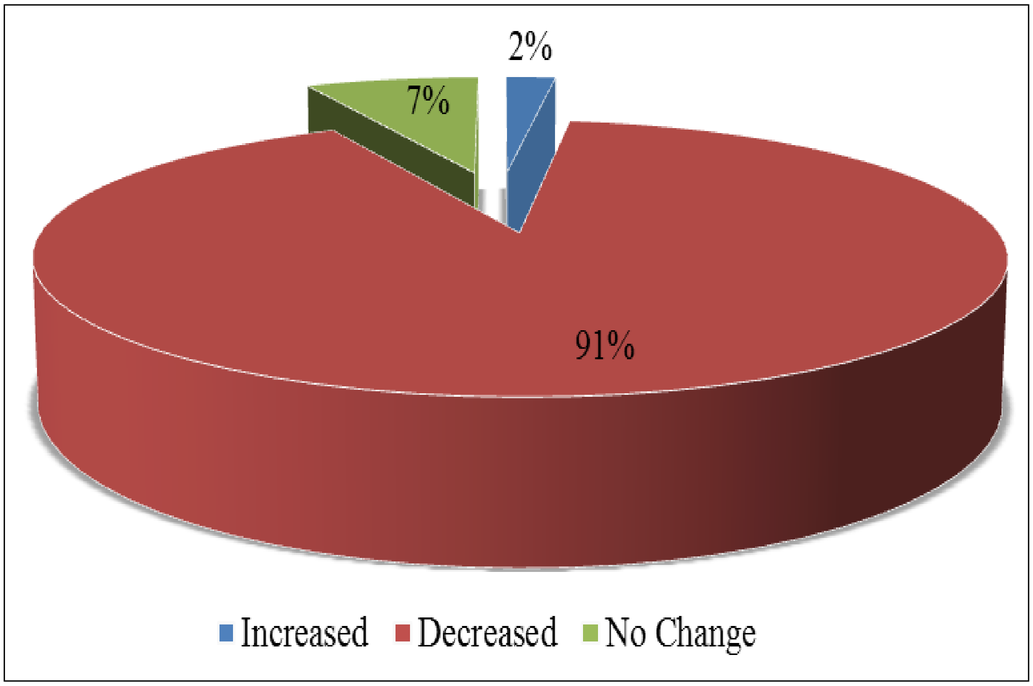
Season	**Crop**	**R^2**	**Model Significance**	**Significance of coefficients**		**Equation**
				Temperature	Rainfall	
Season A	Beans	95.2%	0.001	0.001	0.008	Yield = 18333.3 – 789.35 x Temperature – 0.2 x Rainfall
	Peas	86.7%	0.002	0.007	0.008	Yield=22806.9-1011.6 x Temperature – 0.3 rainfall
	Soybeans	76.7%	0.03	0.04	0.01	1765.74+1.35emperature-74.149 rainfall
Season B	Beans	83.7%	0.004	0.001	0.008	Yield=5879.43-228 temperature - 0.5rainfall
	Peas	73.5%	0.003	0.01	0.03	Yield=12177-521.9 temperature

						– 0.63 rainfall
	Soybeans	73.1%	0.002	0.008	0.0017	Yield = 8130-338 Temperature-0.69 rainfall

Source: Processed from RMC, 2014 and Mareba Sector, 2016

By looking at the formula provided by the model we can see that rainfall and temperature values have negative influence on yield of grain legumes. This means that the yield of beans, peas and soybeans is decreasing from 2005 up to 2014 in both rain seasons. This is in accordance with farmers' views during the questionnaire survey as expressed by the figure 12.

Figure 12: Yield production dynamic change according to the farmers' views



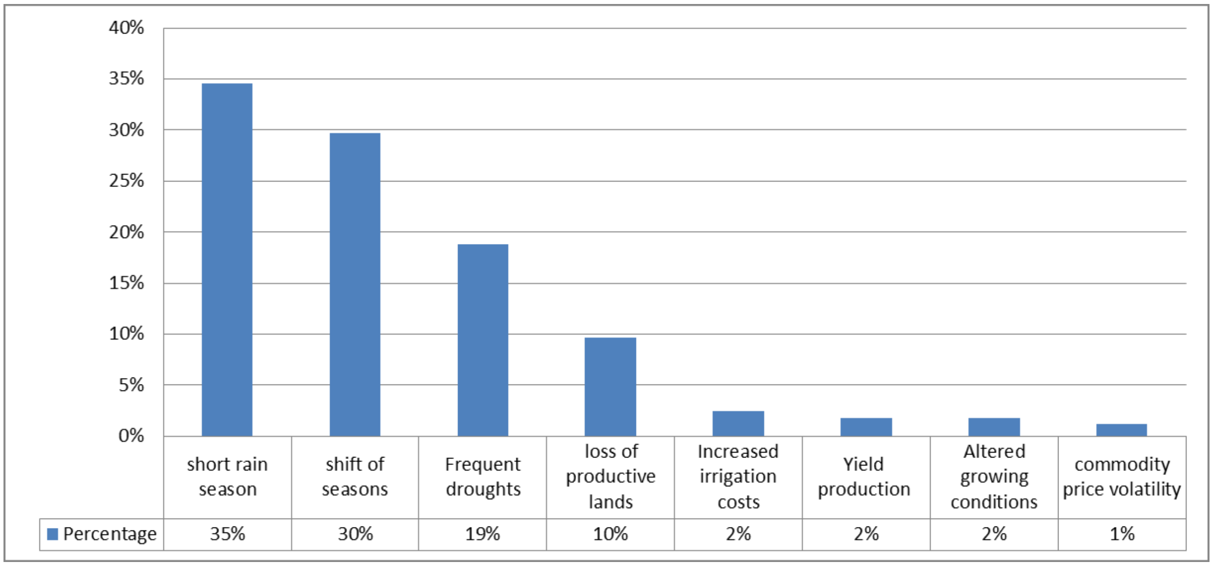
Source: Survey, 2016

The reason of yield decrease is linked to the current weather characteristics namely shift of seasons (delay of the beginning of the rain season), short rain period and abnormalities of precipitations and/or temperatures (See figure 13).

Consequently, market prices are increasing where at the time of field data collection 1Kg of beans and soybeans cost 400Rwf and 500Rwf respectively while it used to cost 500Rwf and 700Rwf for beans and soybeans in 5 years ago. This increase shows that the number of demand increases while the number of supply decreases. The monthly report of Nation Institute of Statistics in Rwanda (NISR) of March 2016 noted that food prices have increased by 7.8% pushing monthly inflation rate by 0.9% in March, 2016. This is due to low agriculture productivity in Rwanda which is the same case of Bugesera district.

Local farmers also noted that the yield of legumes grains has decreased. According to the survey, this is due primarily to the shortening of rainy season, shift of season and frequent droughts. This shows that weather change is the most critical cause of yield decrease (Figure 13). Even though local farmers know it, but they don't have means/capacity to mitigate the impacts of climate variability as discussed in section 4.3.

Figure 13: Perception on the reasons of yield decrease by local farmers



Source: Author, 2016

4.3. Adaptive Capacity

4.3.1. Information and awareness of Bugesera farmers on climate variability and its adaptation

The survey indicated that the level of awareness of farmers on climate change impacts is still low. Results of source of information and believability level among the respondents (Table 13) revealed that the majority (68.7%) of respondents do not believe in climate information got from any source. Most of farmers in Mareba get climate information from the radio with a percentage of 68.7%.30.2% get climate information from meetings with local authorities, 20.8% from meetings. Other sources of information include awareness campaign (2%) and from friends (1%). These results are not far from the findings from CSEA (2011) on the access to climate information by farmers where 72% get information on radio, 24% on Television and 8% in newspapers. But more importantly only 36% used to agree with climate information got from any source. Accordingly farmers cannot find long term solutions for climate change and variability mitigations thus they are experiencing poor harvest.

Table 13: Source of climate Information and level of believability

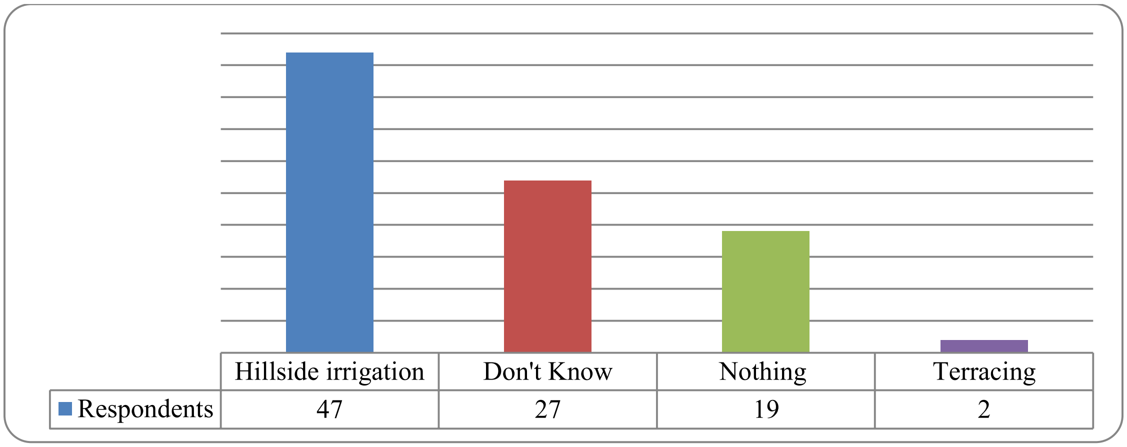
Source of information	Number of people who Belief in the information provided on climate		Number of people who don't believe in the information provided on climate		Total	
	N	%	N	%	N	%
Radio	18	18.2	29	29.3	47	47.5
Meetings	3	3	26	26.3	29	29.3
From friend	0	0	1	1	1	1
Awareness campaign	0	0	2	2	2	2
Radio & meetings	10	10.1	10	10.1	20	20.2
Total	31	31.3	68	68.7	99	100

Source: Author, 2016

The results from the survey (table 13) suggest that peasants are more pessimistic than optimistic as the percentage of farmers who do not believe in climate information is greater than the one of those who believe in it. Hence, it is clear that mitigation to climate variability will be difficult since its information is unknown.

According to climate mitigation awareness 28.4% do not know any practice that can be performed as coping strategy to climate variability issues, 20% responded that nothing could be done to minimize the impacts from climate variability except God or rain maker (commonly known as *Umuvubyi*in Kinyarwanda) who can bring abundant rainfall. Only 2.1% have suggested terracing their lands for better preventing soil nutrients to be washed away.

Figure 14: Perceptions of local farmers on coping strategies against climate variability



Source: Household survey. 2016

The figure 14 reveals the need of irrigation system to perform agriculture in study area and in Bugesera district as well. Other responses “Don’t know” and “nothing” may due to two reasons: On one hand weather conditions are too cumbersome to find out relevant solutions and on the other hand the level of awareness/skills on climate change/variability mitigations that farmers possess is still very low. This is therefore major threat to adapt to current awkward weather conditions in Mareba sector.

4.3.2. Agricultural Performance

In Mareba Sector 95% practicetraditional and subsistence farming by using a hoe and machetes. The rate of using improved seeds is low where only 40% of surveyed households cultivate improved seeds against 60% which cultivate no improved seeds. Furthermore, 42.1% have adopted single crop farming while 57.9% use mixed crop farming. All of the respondents haven’t consolidated their lands and 99% do not cultivate in cooperatives.

Even though it was not mentioned in the questionnaire, I was obliged to ask the reason why they most of farmers prefer mixed crop farming and planting certified seeds and majority raised the issue of land shortage (or land fragmentation). Actually the average land size per household is estimated to 0.69 ha in study area which is slightly lower than the average household land size at national level estimated to 0.8 Ha (NISR, 2014).This indicates that the majority of respondents are small-scale farmers. As indicated by Oyekale (2009) small-scale farmers operate at subsistent level, making them vulnerable and less able to cope with the consequences of climate change. Such farmers also have less likelihood of accessing weather information or capacity to develop technologies on their own.

Furthermore, the shortcomings resulting from not cultivating in groups/cooperatives (Table 14) showed that the main hindrance to adaptation to climate change among the respondents was a poor technical and financial assistance as well as difficult access to improved seeds and agriculture inputs as reported by 42.1% and 42.2% of the respondents respectively. Other limitations emanating from not being cooperatives include difficult access: to loans (7.4%) and to market (4.2%) and poor yield productivity reported by 4% of the respondents.

Table 14: Shortcomings of not cultivating in groups/cooperatives

Shortcomings of not cultivating in groups/cooperatives	Frequency	%
Not easy to obtain technical and financial support	40	40.4%
Access to agriculture inputs is difficult	15	15.2%
Access to improved seeds is difficult	25	25.3%
The yield production is not good	4	4.0%
Access to loans is difficult	7	7.1%
It is not easy to have access to market	4	4.0%
No Answer	4	4.0%
Total	99	100%

Source: Author, 2016

The results presented in table 14 revealed that farmers are experiencing self-coaching system in their daily farming activities from land preparation up to harvesting period. This is well indicated by the table 15 of institutions involved in agriculture support. Therefore, as farmers are not skilled enough coping strategies couldn't offer enough contribution in adapting to climate change and variability in agriculture thus the sector is becoming more vulnerable.

Table 15: Institutional performance in supporting agriculture in Mareba Sector

Source of Support	Number	Percentage
NGOs	47	47.5%
Government	33	33.3%
Private institutions	8	8.1%
Relatives	6	6.1%
Bank	5	5.1%
Total	99	100.0%

Source: Author, 2016

4.3.3. Technology applied to improve seeds that may resist to climate variability and its efficiency in Bugesera

Currently the available varieties of seeds resisting to current weather conditions are predominantly: ***Mutiki***and***Shyushya***. Those varieties of beans have given the names in Kinyarwanda by referring to the level of adaptation. ***Mutiki*** variety means the type of beans which adapt to the insufficient rainfall and poor soils while ***Shushya***means the type of beans with a very short cycle period.

Those varieties are from NAEB and are given to the farmers after paying a half of the cost. But unfortunately when the rainfall delay the farmers do not use to take the seeds because of not being sure that the harvest will be good. Only few of the farmers (3%) are capable to keep the seeds for next season after harvesting season, 10% keep the seeds but if rainfall delay cook them and the remaining 87% percent are not capable to reserve the seeds for next season.

Though these varieties have significant resistance capacity to climate variability, the farmers also state that the issue is irregular rainfall during a season.

> "*Imvura igira gutya ikadushuka tugatera ubona ko rwose iriho nta kibazo, ariko twamarakuyishyira hasi igahita yimanika"* said one of the interviewed farmers which means "*We plant while we see that the*

rainfall are abundant enough at the extent that we are sure to have a good rainy season but after planting it stops".

This could be a major hindrance while developing certified seeds possessing strong resistance.

4.3.4. Mitigation practices against climate variability

Among the measures that could be undertaken to increase agriculture productivity from rain fed agriculture of grain legumes include: hillside irrigation, agro-forestry, planting the seeds possessing strong resistance on dryness/drought, water harvesting for irrigation purposes among others. Findings from the questionnaire survey have shown that the local authorities of the case study are trying their best to give their support in climate variability mitigations by facilitating farmers to obtain irrigation machines for watering legumes cultivated nearby marshlands and obtaining improved seeds as well (i.e. ***Shyushya*** and ***Mutiki***).

The surveyed farmers also confirmed that they use manure, chemical fertilizers and agro-forestry as coping strategies against climate impacts and increase rain fed agriculture productivity (See table 16).

Table 16: Available practices aiming at reducing climate variability impacts and increase agriculture productivity in case study

Id	Practices To Reduce Climate variability Impacts	Frequency	Percentage
1	Irrigation and improved seeds	42	42.4
2	Improved seeds, Manure and Chemical fertilizers	16	16.2
3	Using improved seeds adapted to current weather conditions	13	13.1
4	Irrigation	11	11.1
5	Use of manure	6	6.1
6	Adopting to agro-forestry	4	4.0
7	Manure and Agro-forestry	3	3.0
8	Harvesting water to be used during dry season	2	2.0
9	Use of chemical fertilizers	2	2.0
	Total	**99**	**100.0**

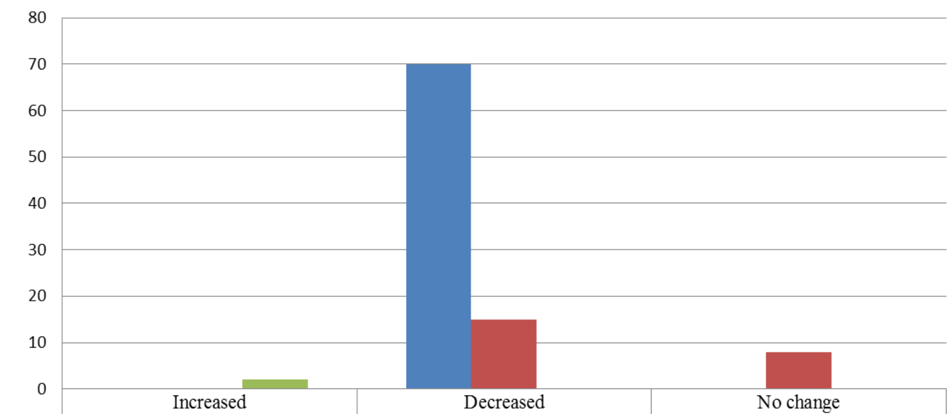
Source: Author, 2016

Table 16 shows that improved seeds adapted to current weather situations and irrigation takes the first place among all practices to stabilize and/or increase agriculture production. Even though these practices are in place, the effectiveness is still questionable because the available hillside irrigation concerns the plots that are close to marshlands just in few meters from water pond. In addition they are few marshlands in study area with only 221Ha out of 5,590Ha of total land. This reveals that there is very little number of farmers who can benefit from irrigation because the irrigable land is too small thus agriculture depends on rain fed season.

According to irrigation tools/equipments, farmers who have got machines for irrigation are only 9 in whole Sector as said the agronomist officer of Mareba sector. Other farmers who perform the irrigation use to rent the machines and this increase the irrigation cost, thus it is discouraging small farmers.

The use of improved seeds as mitigation measure against climate variability was found also ineffective. According to the Cell Socio-Economic and Development of Cell (SEDO), the rate of using improved seeds and agriculture inputs is abominable. In the interview held on the 23rd March, 2016 with Rango Cell SEDO, he has said that due to the delay of rainfall farmers use to have fear that the season will not be good. Consequently they are not committed to buy improved seeds and agriculture inputs. He added that it has been observed that even some farmers use to cook portion of seeds reserved for planting when the rainfalls delay. Because of low income, most of inhabitants fail to use improved seeds at 57.6% against 38.4% farmers using certified seeds. Thus, this is among the important reasons for yield decrease as argued by local farmers covered by the interview (See figure 15).

Figure 15: Monthly income vs historical crop yield sensitivity



	Increased	Decreased	No change
<15,000	0	70	0
15000-40000	0	15	8
>40000	2	0	0

Source: Author, 2016

2% representing yield increase may justify how to cope with the current weather conditions in order to increase the productivity from agriculture sector require considerable economic capacity. This is explained by the figure 15 where those who have replied that the income is increasing are those who are richer than others considering monthly income, "income doesn't change" has answered by some from middle income and those who answered that crop yield productivity is decreasing are from low income (around 82%) and from middle income.

4.3.5. Availability of infrastructure and agricultural equipments/tools

In Mareba Sector, the available infrastructure include 9 machines used to irrigate field plots planted with leguminous (such as tomatoes, vegetables, onions to name but few) located in the immediate vicinity of marshlands. There is also the public food store set to encourage farmers to anticipate famines. There is also a marshland irrigation scheme for rice cultivation. No any infrastructure set for hillside irrigation. These available infrastructures are not enough to be sure that climate related impacts are highly mitigated for the benefits of rain-fed agriculture. Otherwise, the researches of developing seeds of high resistance to weather conditions could be improved and more sensitizations in using certified seeds could be reinforced.

4.3.6. External response interventions and government intervention

To mitigate with climate variability, the authorities of Bugesera district sought an agro-ecological approach that would be both regionally adapted and culturally specific. Thus, as one of the measures, the authorities started a reforestation programme in 2005, to reverse the trend.

"*We didn't take care of our natural resources. People destroyed the environment by cutting down trees and there was no mechanism in place to replace them. Since the government took measures to fight against deforestation in 2005, the area began to receive regular rainfall and today, farmers are making regular harvests*," Rwagaju says to the Rwandan Cook.

With the intervention of local government, farmers have been significantly facilitated to access fertilizers and better seeds besides offering advice on best farming practices.*"I have managed to transform my farming activities, with the advice of local authorities on how to use fertilizers for better production. We have been receiving selected seeds and* *organic fertilizers where we pay 50 percent while the other half is offset by the local authorities*" says one of the interviewed farmers.

Another solution to ensure food security in the area was the construction of silos to store produce, through the support of a food security support project known by its French-acronym PASAB (*Projetd'Appui à la SécuritéAlimentaire au Bugesera*) this programme, run by the Catholic Church NGO Caritas, has played a vital role in shielding area residents from famine.The food storage programme was first initiated in the Eastern Province. It was mandatory for every citizen in the province to stock a little quantity of crops harvested in public storages (usually referred as silos). The grain storage programme has considerably helped in fighting against hunger and reports indicate that agricultural yields tripled within a short time as villagers set up the cereal bank to store grain.At least every cell has its own grain storage facility in addition to 16 big silos that the PASAB project put up in every sector.This is because the district has applied modern agricultural interventions and maximizing community leadership and participation, which have transformed it from what was previously known as 'the poorest places in Rwanda' to one that has become a model for development.Increasing production can come at the expense of further limiting the available land for agriculture, especially in light of the aggressive efforts to intensify agriculture. Improved methods of environment management will be required to ensure that agricultural practice is sustainable.

INTERVENTIONS

(a) Humanitarian food aid relief. The WFP and several NGOs (notably Caritas, World Vision, and Red Cross) have provided food supplies mostly targeting the most vulnerable groups i.e. widows and orphans.

(b) Food-for-work programmes implemented by WFP, World Vision, Caritas and other agencies. Under this arrangement, local people exchange their labor for food but they work on communal projects such as roads, construction of bridges and schools.

(c) Restrictions on sale of food stuffs: in order to regulate food prices, the Government announced a ban on sale of all agro-produce to private businesses, and directed farmers to sell to local cooperatives, reportedly to avoid speculative business people. In addition, some NGOs have been buying off produce and storing it to be resold to the communities during times of crisis.

(d) Encouraging food storage through communal food banks. Under this strategy, aiming at anticipating famine, each household is required to deposit some proportion of their food harvest to the public food store at sector level (no silos exist). This food is then recorded and in time of crisis, it can be withdrawn. In case this approach is applicable, it could have significant contribution to agriculture performance because of two reasons: First, it helps farmers to have saving spirit thus preventing from extravagant consumption; second, as the farmers use to cook the quantity of pulses reserved for seeds when rainfalls delay (during famine period), it could not happen again and it can facilitate the suppliers of improved seeds like HarvestPlus[1] to make sure that targeted farmers have availed seeds for exchange. Unfortunately, this approach doesn't exist anymore.

(e) Creating off-farm employment opportunities. The Labor intensive public works programme (HIMO) implemented a tree planting programme to restore tree cover and conserve the environment while providing employment for local people (UNDP, UNEP, GoR, 2007). This programme has reintegrated in Bugesera district when droughts used to devastate the region.

[1]**HarvestPlus** is a project of the Consultative Group on International Agricultural Research (CGIAR) that aims to breed micronutrients into staple food crops to fight hidden hunger. It focuses on Vitamin A, Zinc and Iron as main micronutrients that are rare in the diets of the poor, as proven by the WHO. In Rwanda, it operates in 27 districts and Bugesera is included. In partnership with RAB, HarvestPlus breeds and disseminates High Iron Beans (HIB).

Figure 16: Planted trees in Bugesera around the roads in order to lessen climate impacts and provide jobs

Source: Author, 2016

4.4. Government Policies Implications

Climate change is recognized at the highest level of Government as a potential threat to productivity and sustainability of the agricultural sector and livelihoods of Rwandans. As a result, GoR has implemented a number of policy initiatives including: mechanisms to implement provisions of international climate change conventions (implementation of NAPA); reforming public institutions to include climate change management functions; and mainstreaming climate change within policy processes. The environment and natural resources, and low carbon growth strategy are recent policy strategies that reflect climate change adaptation priorities.

4.4.1. Specific climate change actions in the agricultural Sector in Rwanda

The National Adaptation Programmes of Action to Climate Change (NAPA) report suggested immediate and urgent actions to be undertaken in different socio-economic sectors of the country. In agriculture, identified priorities are: Integrated management of water resources; Establishment of information systems for hydro-agro-meteorological warning and rapid intervention; promotion of income generating activities other than agricultural ones; promotion of intensive agri-farming and introduction of varieties resistant to environmental conditions (MINITERE, 2006).

In study area these actions are not yet empowered enough to offer abundant benefits to farmers since the access to climate information is still very low and inefficient, most of the farmers (95%) are relying only on rain-fed subsistence agriculture with traditional practices.

4.4.2. Key climate change adaptation measures for agriculture appropriate for Rwanda

As part to the United Nations Framework Convention on Climate Change (UNFCCC), Rwanda is taking precautionary measures to predict, prevent or reduce the causes of Climate Change and to minimize their harmful effects on sustainable development (MINIRENA, 2011). The measures that have been taken include: introduction of new crop varieties, especially early, resistant and adapted to climate; improved technology including water efficient irrigation systems; drought tolerant and fast growing crop varieties; information dissemination to farmers and links with researchers and extension workers; promotion of income generating and mutual development activities and empower farmers and farmers' groups with climate information and adaptation toolkits.In addition the booklet entitled **"Tumenyeguhanganan'imihindagurikirey'ibihe"**standing for "Adapting to Climate Change" in Rwandan context which is an education and a sensitization tool for the general public (MINIRENA, 2011).

Though its importance, this booklet is not available to farmers and farmers' groups of Mareba Sector which accelerates the delay of government programmes implementation.

4.4.3. Overview of Rwanda's Agricultural Policy Process

Rwanda's Agricultural sector is structured in a decentralized framework that comprises of 3 levels: the central administrative and planning level; regional level and the peripheral level (community service providers). An important area to consider is the Local Performance Contracts (*Imihigo*). Rwanda's policy process is initiated through a complex interaction of national aspirations, international commitments and local health challenges. Rwanda's Policy is designed and implemented in the context of the country's Vision 2020, the need to translate Government Political Plan (2010-2017) into actual results, and achieving the Millennium Development Goals (MDGs) targets related to agriculture. These are; eradicate extreme poverty,hungerand malnutrition (MDG 1); promote gender equality and empowerment of women (MDG 3); health related goals aimed at reducing infant mortality and improving maternal health, combating major diseases (MDGs 4, 5 and 6) and ensure environmental sustainability (MDG 7) are of major importance to agriculture.

Unfortunately the level of achieving these targets is still very low if we consider the information previously discussed. Accordingly, Mareba and Bugesera in general are suffering and will continue to experience climate related impacts in agriculture.

4.5. Climate Impacts and Agriculture Vulnerability

In previous sections I tried to highlight exposure and sensitivity of grain legumes to climate variability/change. In this section I will try to assess climate impacts and evaluate agriculture vulnerability.

4.5.1. Climate impacts

Due to the effects of climate change/variability since 30 years ago, Bugesera has become vulnerable to the agriculture performance. For instance, the information got from agronomist officer at sector level, SEDOs and local farmers have clarified that some crops like yams, sweet potatoes, Irish potatoes, peas and cassava are no longer potential in farming activities in the region.

"*Currently farmers use to plant crops which can survive to irregular rainfall or to short rainy season like certified beans. Other crops like Peas, cassava and yams are no longer potential in this Sector*". Said the SEDO of Rugarama cell.

The most cultivable crops are therefore, beans (certified seeds), leguminous around the marshlands, sun-flows and maize. All of these crops in general try to adapt to current weather conditions as said by 74% of surveyed farmers. This implies that Mareba Sector (as well as Bugesera as whole) is among drought prone areas with associated various weather risks threatening the performance of agriculture. Among the weather risks (Table 17) that are being observed in the study area include change of planting dates, droughts; food insecurityare the most famous (WFP, 2010).

Table 17: Weather Risks in Mareba Sector

Type of risks	Frequency	Percent
Change of planting dates	50	50.5
Droughts and Food insecurity	26	26.3
Both droughts and Food insecurity	13	13.1
Both Food insecurity and Change in planting dates	6	6.1
Snow	2	2
Floods	1	1
Total	**99**	**100**

Source: Author, 2016.

From the table 17, the change of planting dates is the most problematic among others with 50.5%. The change mainly refers to the delay of starting of rainy season. According to the droughts and Food insecurity, during field data collection farmers were confirming that from 2015 there is food insecurity period in the region surnamed "***Warwayeryari?"*** which means***"When did you fall ill?*** The farmers also have informed that during last 10 years at least three Food insecurity events have been accured in 2005-2006, 2008 and 2015-2016 while only in 2013 the yield has been abundant. Other years have not been recognized to have good or bad harvest but marginal. From this perspective, we can see how the region is more vulnerable.

4.5.2. Agriculture Vulnerability

The agriculture performance, information that local farmers have on climate change/variability and its adaptation, available infrastructure and economic capacity make the agriculture sector of Mareba Sector (and Bugesera in general) more vulnerable to climate change and vulnerability.

In fact, as it was aforementioned in 4.2 there is considerable climate variability with increasing temperature and irregularity of rainfall as well. Thus optimum temperature and rainfall for development of peas and soybeans are not the same as current temperature and rainfall threshold. As result the yield from grain legumes is decreasing! Due to the deficiency of information on climate change/variability and its mitigations coupled with low economic capacity, the farmers of the case study are incapable to cope with current weather conditions in their daily farming practices. As the current practices such as irrigation nearby the marshlands and using improved seeds of beans and maize are not effective as highlighted in previous sections, the agriculture of Mareba Sector and other drought prone areas of Rwanda will seriously experience low productivity.

As it has been identified that people who use to get higher monthly income than others recognize the increase of yield, more efforts should be put on seeking how to increase off-farm activities in the case study.

CHAPTER FIVE: CONCLUSION AND RECOMMENDATIONS

This chapter gives the conclusion, comparing the research findings to the research objectives and questions. Hence the formulated research hypothesis is validated. Finally, recommendations with regard to climate variability adaptation in agriculture sector in droughts risks zone are proposed.

5.1. Conclusion

The objective of this study was to assess the adaptation to climate Variability in Agriculture Sector in Rwanda, especially in Bugesera. To achieve this, I elaborated the specific objectives and they have been achieved at the following levels:

Assess exposure of grain legumes to climate variability in Bugesera

To respond to this objective, I referred to the Time series analysis of climate data since 1971 up to 20114 using MAKESENS model. Then after, I tried to assess yield dynamics of grain legumes for last decade ANOVA test. It has been identified that for both rainy seasons (season A and B) temperatures are increasing pitifully.

Mean temperature analysis has shown significant increase (0.001) of 0.39 ^{0}C and 0.46^{0}C per decade for season A respectively. From these figures we notice that Season B is more exposed to climate variability than season A. Rainfall analysis by contrast has identified a slight decrease with no significant trend. Through years rainfall is unusually low or high. Moreover, it has been identified that the quantity of rainfall in April and May (for season B) is decreasing while it is decreasing in March. This could be an awkward situation for farmers because they plant in March and crops lack rainfall during their development. In season A, the rainfall of October and November is increasing while it decreases in December. From this perspective, the harvest can be poor since grain legumes (beans, peas and soybeans) development requires frequent rainfall during at least 120 days (3 months) but still the season B is more vulnerable than season A as previously introduced.

Another major point that has been identified is the rapid increase of minimum temperature and minor increase of maximum temperatures which decreases Diurnal Temperature Range (DTR) which can impact on plant development like decrease in internode length, as well as the small decrease in height, stem thickness and leaf area could add up to a large decrease in photosynthetic area. In addition, the analysis of minimum and maximum temperatures dynamics per each decade from 1970s has identified that so far they provide an acceptable temperature threshold for beans development but they are not optimum for peas and soybeans. In relation to rainfalls, they are becoming inadequate to satisfy the development of grain legumes (Beans, peas and soybeans) thus the harvest can decrease.

Investigate the sensitivity of grain legumes' yields to climate variability in Bugesera

After analyzing the vulnerability of grain legumes to climate variability, I was interested to assess the level of yield sensitivity vis-a-vis climate variability. As it was not possible to obtain yield data of long period, I preferred to take the range 10 years from 2005 to 2014.

Temperatures and rainfall, have predicted the changes in yield of all grain legumes (beans, peas and soybean). Furthermore, the yield of grain legumes is negatively correlated with temperature and positively with rainfall which means that the yield of grain legumes decreases as temperatures increase and rainfalls decrease or vice versa.

Analyze the ability of the farmers in case study to adapt to the effects of exposure and sensitivity

The indicators used to extract information from this objective were: agriculture practices, people's awareness on climate and its variability, access to technology and climate information, economic capacity of local farmers, infrastructure variability and institutional capacity as well as distribution of resources.

It has been identified that most of the farmers use traditional practices while cultivating by using hoe and machete. 99% of the farmers do not cultivate in cooperative thus it is very difficult to have access to technical and financial assistance and to obtain agriculture insurance. 58% use to adopt mixed crop farming against 42% who use to adopt single crop farming. In addition only 40% of the farmers in case study plant certified seeds while 60% do not cultivate certified seeds. These practices show that the level of mitigation to climate variability is not good to sustain yield from rain-fed agriculture thus more efforts are needed.

Other available practices aiming at coping with climate variability include irrigation (which is being done at few meters from the marshland) and use of manure and chemical fertilizers (with 16.2% of farmers) but also we cannot be say that they provide enough contribution at the level we can ensure effective mitigations against climate impacts (which are droughts, Food insecurity events, snows and change of planting date). The major threat to access these practices is poverty where the average monthly income is 19,232Rwf or 641Rwf per day which is under pervert line. The cumbersome situation is for widowed/divorced headed families (that are around 33%) whose average monthly income of 3,844Rwf per month or 128Rwf per day. These families experience extreme vulnerability where no family earns more than 6000Rwf per month or 200Rwf per day.

According to the access of information, the majority get information from radio and meetings with proportion of 47.5% and 29.3% respectively. 20.2% hear climate information from both radio and meetings while 2% and 1% get it from awareness campaigns and friends respectively. Unluckily, the level of believability is very low where only 31.3% do believe on climate information got from any source and 68.7% do not on pretext of lack of truthfulness because the climate that farmers use to experience is different from the information provided.

Finally, it has been identified that to cope with current weather conditions in order to increase yield production of rain-fed crops (such as beans, soybeans and peas) requires strong and expensive measures that anybody from the case study can afford. This is justified by the fact that farmers who have reported that the harvest is increasing are those who gain high income than others; the yield productivity is constant for middle income families while it is decreasing for low income families. This shows that currently the agriculture performance requires many investments.

5.2. Recommendations

Based on the findings the following can be recommended:

Land consolidation and forming cooperatives: Land consolidation and cultivating in cooperatives could be a good approach to adapt and/or mitigate with climate change/variability related impacts. Farmers could get technical and financial assistance easily from government, NGOs, public and private institutions and Organizations. Financial assistance could be loans or donates and technical assistance on its side can be techniques in cultivating or advices on crop or fertilizers or diseases mitigations.

MINAGRI in partnership with local authorities are advised to reinforce the process of consolidation of the use of small plots of farm lands in order to improve land management and agriculture productivity as it was endorsed by the Organic Law established in 2005 determining the use and management of land in Rwanda.

Improving economic capacity of local farmers: It has been identified that the increase of productivity for rain-fed crops such as beans, soybeans and peas is being experienced by farmers who earn higher income than others. Small farmers are advised to apply for loans near financial institutions so that the farmers can buy appropriate equipment for farming and watering plants and buy improved seeds.

Cultivating seeds that are resilient to climate variability and if possible start other off-farm activities: Current weather conditions are uncertain! On one hand farmer's use to plant while the rainfalls are abundant but it stops raining so that the harvest becomes poor! On the other hand when it has delayed to rain, farmers also plant anywhere with no certitude of having good season. All of these challenges that farmers from the case study use to experience could result in food shortage, reduction of socio-economic sustainability to name but few.

The use of seeds resilient to climate variability could be an effective mechanism for reducing the losses farmers suffer due to natural calamities such, droughts, and outbreaks of pests and diseases. Furthermore, farmers have to seek how to improve off-farm activities so that they cannot rely on agriculture only.

Improving Climate information reliability and dissemination: It is not easy to develop adaptation measures to something with unknown information. As many of the farmers do not agree with the information that is being disseminated, it could be very important if climate information dissemination framework is developed and adapted so as to increase farmers' awareness on climate change/variability.

Furthermore, it could be helpful if MINAGRI in partnership with REMA, NGOs and other relevant institutions and organization as well to introduce the component of environment in existing extension services.

Continuous researches: Researchers, universities, RAB, MINAGRI, MINIRENA, REMA and other relevant institutions are recommended to conduct more researches in the field of climate change/variability and agriculture in sensitive areas like Bugesera in order to identify more challenges or issues that agriculture (or farmers) is facing. The results could have significant impacts on the development of farmers and country as whole.

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Appendices

Appendix 1: Questionnaire for household survey

Instructions

1. *Circle the correct response or writing down the appropriate code as indicated.*
2. *For open-ended questions, write down the answer.*

Interviewee code …………. Date: ………/………/2015

District ……………..…… Sector: …………………..……… Cell: ……………………………

I. HOUSEHOLD STRUCTURE

1	**Gender**	Male=1	Female=2	…………………………………………..		
2	**Marital status**	Single=1	Married=2	Widowed=3	Divorced =4	……..

3. Number of people living in family? …………………

4. What is the level of education of household members?

Household member		Primary=1, Secondary=2, Bachelor=3, Masters=4, PhD=5, TVT=6
Householder		
Spouse		
Adult children	1	
	2	
	3	
	4	
	5	

5. When have you settled here? ……………………………..

6. Do you own land?

Yes	1
No	2

7. If you have land, how big is it in Ha? …………………………..

II. ADAPTIVE CAPACITY (FINANCIAL AND AWARENESS)

8. What is the job of family members?

Household member		**No job=1, Farmers=2, salaried=3, Business=4, casual job=5**
Householder		
Spouse		
Adult children	1	
	2	
	3	
	4	
	5	

9. How much money in average do you earn per month?

Household member		**Earnings in Rwf**
Householder		
Spouse		
Adult children	1	
	2	
	3	
	4	
	5	

10. How do you use this income? (Fill the table below with appropriate number as indicated)

Domain	**Priority** (1: very high, 2: High, 3: medium, 4: low, 5: very low)
Agriculture	
Off-farm activities	
Education	
Health issues	
Others (Specify if any)	………………………………………………………………………. ……………………………………………………………………….. ……………………………………………………………………….. ………………………………………………………………………..

11. Which support do you gain from third parties?

Source of support	Financial (money, seeds, inputs, …)	Technical assistance	Loans/credits	Infrastructure	Other (Specify)
Government	1	7	13	19	
NGOs	2	8	14	20	
Private institutions	3	9	15	21	
Banks	4	10	16	22	
Relatives	5	11	17	23	
Others	6	12	18	24	

12. Where do you get information on climate?

Radio	1
Meetings	2
Trainings	3
Newspapers	4

TV	5
From friend	6
Awareness campaign	7
school	8
Other (Specify)	……………………………………………………. ……………………………………………………. ....

13. Do you believe in the information provided on climate?

Yes	1
No	2

14. If you do believe in it, do you find it reliable?

Yes	1
No	2

15. According to you has the climate changed?

Yes	1
No	2

16. If it has changed, what are characteristics showing the climate change?

No	Characteristic	Choice
a	Short rain season and long dry season have shortened?	1
B	Shift of seasons (delay of beginning rain season)	2
c	droughts are becoming frequent	3
d	Reduction of crop yield	4
e	Altered growing conditions and seasons	5
f	Increased exposure to pests and diseases	6
j	Commodity price volatility	7
k	Increased irrigation costs	8
l	Loss of productive land	9
m	Do not know	10

17. Which practices already in place aiming at reducing the impacts of climate variability and increase agriculture productivity?

Irrigation	1
Harvesting water to be used during dry season	2
Using improved seeds adapted to current weather conditions	3
Use of manure	4
Use of chemical fertilizers	5
Adopting to agro-forestry	6
Terracing	7
Liming	8
Agriculture made in greenhouse	9

18. According to you, how do you judge the efficiency of mitigation/adaptation techniques?

Excellent	1

Very good	2
Somehow good	3
Good	4
Not good	5
Bad	6
Very bad	7

III. FARMING PRACTICES

19. Which tools do you use while cultivating?

Hoe	1
Machines	2

20. What type of agriculture do you practice?

Intensive subsistence farming	1
Traditional subsistence farming	2
Commercial agriculture	3

21. Which cropping system do you use?

Single-crop farming	1
Mixed-crop farming	2

22. What type of seeds do you use to cultivate?

Certified seeds	1
Non certified seeds	2

23. Do you cultivate in cooperatives?

Yes	1
No	2

24. If you do cultivate in cooperatives, have you adopted land consolidation?

Yes	1
No	2

25. According to you, what could be the shortcomings of being in cooperatives or not?

	Being in cooperative	Not being in cooperatives
Not easy to gain technical and financial support	1	7
Access to agriculture inputs in difficult	2	8
Access to improved seeds is difficult	3	9
The yield production is not good	4	10
Access to loans is difficult	5	11
It is not easy to have access to market	6	12

26. What do you think could be done to minimize the impacts of climate variability and increase agriculture productivity?

IV. YIELD PRODUCTION, TRENDS AND SENSITIVITY

27. What is the average cost of production per season?

Cost of inputs	…………………………………
Land lent	…………………………………
Labor cost	…………………………………..

28. What types of fertilizers or inputs are used?

NPK	1
Urea	2
Organic manure	3
Lime	4
DAP	5
None	6

29. How crop production is changing from last years ago?

Increased	1
Decreased	2
No change	3

30. If it has changed, what could be the cause?

Productivity has been increased		1
Quality of seeds has been	Improved	2
	Not Improved	3
Soil fertility has been	Increased	4
	Reduced	5
More investments have been		6
Other (Specify) ……………………………………………………………………………………….... ……………………………………………………………………………………………………… ……………………………………………………………………………………………………		

31. If the production has decreased, what do you think could be the cause of such change?

Shift of season	1
Insufficient rainfall	2
High temperatures	3
Infertile soils	4
Soil erosion	5
Land fragmentation resulting from high population growth	6
Other: ……………………………………………………………………………………. ………………………………………………………………………………………………… ………………………………………………………………………………………………… …………………………………………………………………………………………………	

V. CLIMATE RISKS

32. What are the specific weather risks do you use to experience?

Droughts	1
Famines	2
Floods	3
Change of planting dates	4
Crop diseases	5

33. If you are exposed to weather risks, how do you currently manage them?

Nothing	1
Engaging in off-farm activities	2
Migration	3
Cultivating in marshlands	4

34. In how many years out of 10 are yields reduced because of drought? ………..……………

35. In which of the last 10 years do you recall having the most favorable weather for production? ………

36. What do you do if rains are insufficient for planting?

Plant crops resisting to dryness	1
Do not plant	2
Plant anyway	3

37. Do you ever not plant if rainfall is not good?

Yes	1
No	2

38. If yes how many time ……………….

39. What crops that have been abandoned due to the climate change?

1. ……………………………………………………………………………………………………
2.……………………………………………………………………………………………………
3. ……………………………………………………………………………………………………
4. ……………………………………………………………………………………………………
5.…………………………………………………………………………………………………… 6. ……………………………………………………………………………………………………
7. ……………………………………………………………………………………………………
8. ……………………………………………………………………………………………………

40. According to you, what are the crops that are prioritized or replaced the ones existing before the climate change occurrence? (List them)

1	
2	
3	
4	
5	

41. Additional comments

………
………
………
………
………
……………………………………………………………………………………………

Thank you!

Appendix 2: Interview Guide Questions

1. Nowadays climate variability and change is a crosscutting issue. According to you, how can you see the figure of climate change/variability in Bugesera region? Can we say that Bugesera is highly exposed to climate change/variability issues?

………
………
………
………
………………………………………………………………………………………

2. Have you ever noticed the impacts of climate change/variability in this region? If they are some, what are they?

………
…………………………………………………………………………………
………
………
………
………

3. What are the available practices aiming at coping with the climate variability/change impacts and adapt to new changes?

………
………
………
………………………………………`

4. What are the practices for future aiming at coping with the climate variability/change and adapt to new changes?

………
………
…….

5. How do you deliver the available services and/or practices to farmers pointing to mitigate with climate change/variability impacts?

………
………
………
…

6. Which information and skills do local farmers of Bugesera district have concerning the climate variability and its adaptation? How do you increase their awareness?

………
………
………
………

7. What challenges do you face while mitigating with climate change/variability impacts?

………
………
………
………
……………………………………………………

8. Do you think that farmers will be able to cope with climate change in the near future (5years)?

....
....

....
....
9. Additional Comments
………
………
………
………
……………………………………………………………………………………………

Thank you for your participation!