Assessment of Climate Variability, Post-Harvest Losses and Household Food Security in Kayonza District, Rwanda

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List of Acronyms

APSIM – Agricultural Production System Simulator

ASAP – Adaptation for Smallholder Agriculture Programme

CARI – Consolidated Approach to Reporting Indicators of Food Security

CFSVA – Comprehensive Food Security and Vulnerability Analysis

CIP – Crop Intensification Programme

FAO – Food and Agriculture Organisation of the United Nations

FARA – Forum for Agricultural Research in Africa, Accra, Ghana

GDP – Gross Domestic Product

IFAD – International Fund for Agricultural Development

IPCC – Intergovernmental Panel on Climate Change

KIPPRA - Kenyan Institute for Public Policy Research and Analysis

MINAGRI – Ministry of Agriculture and Animal Development

NISR – National Institute of Statistics Rwanda

PASP – Climate Resilient Post-harvest and Agribusiness Support Project

PHHS – Post Harvest Handling and Storage Infrastructure

REMA - Rwanda Environmental Management Authority

SPIU – Single Project Implementation Unit

SPSS – Statistical Package for the Social Sciences

USDA – United States Department of Agriculture

WFP – World Food Programme

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EXECUTIVE SUMMARY

Attention shifted to addressing the challenge of postharvest losses after the 1970s food crisis. But once food commodity prices started to fall, no one seemed to care anymore. Now postharvest loss is gaining attention again because of the blow that climate change is dealing with farmers' harvests across regions of the world. Through impacts like shifting and unpredictable rainfall patterns, prolonged drought events, flooding, bush fires, desertification and losses that occur during postharvest handling, climate change causes serious loss of agricultural harvests leading to economic loss and threatening food security of smallholders. Currently, Sub-Saharan Africa is experiencing a worsened food insecurity because of its low preparedness to climate change. This is a region that is predicted to add an additional 1 billion to its current population by half this century. How then does Africa feed Africa?

The United Nations International Fund for Agriculture Development in March 2014 agreed to fund a Climate Resilient Post-harvest and Agribusiness Support project with support from the Government of Rwanda, Adaptation for Smallholder Agriculture Programme and other players. This project, which has three components, has the overall goal of alleviating poverty, increasing rural income and contributing to overall economic development of Rwanda. One of these components is the post-harvest climate resilient agri-business investment support that involves supporting farmers with the acquisition of relevant low-carbon postharvest infrastructures that can reduce postharvest losses and increase smallholders' incomes.

This study assesses PASP with particular focus on current state of losses, adoption of climate resilience methods and technologies, and the impacts of these on food security for maize, beans and dairy farmers in Kayonza District. Kayonza District was chosen out of the twelve districts in Rwanda where PASP operates. This is because of its peculiar climate change vulnerability. Three hundred and fifty-six (356) farmers were sampled from thirteen PASP-beneficiary cooperatives in this district. Out of these cooperative members, 57 were from dairy cooperatives and the rest 299 were farmers in maize and beans cooperatives.

The household size of the respondents ranges from 1 to 12 members with an average of 5.3 which is modestly close to 4.7 reported by the country's institute of statistics. One hundred and eighty-one (equivalent to 51%) of the respondents are females. Majority (46.9%) belong to the 31-45 years age bracket followed by 46-60 years age bracket (29.2%). Out of 335 respondents, only 7.5% own land that is over 2 ha in size; 9.3% own between 1 and 2 ha of land; 45.6% have between 0.5 and 1 ha and 37.6% own less than 0.5 ha of land meaning

majority of the farmers are between very small cultivators (under 0.3 ha) and medium cultivators (0.9 to 3.0 ha) according to NISR. We found in our respondents that females own smaller lands than male: the females own more of the less than 0.5 ha and between 0.5 and 1 ha while the males own more of 1-2 ha and greater than 2 ha lands. The dairy farmers have between 2 and 30 cows and produce between 5 and 60 litres of milk per day. Majority of the farmers (88.2%) depend solely on farming as their source of income while only 11.8% engage in other economic activities not related to farming. However, many of the farmers diversify their agricultural production. Out of five groups of agricultural activities (growing maize, growing beans, rearing cows, rearing small domestic animals like goals, fowls and pigs, and growing other crops than maize and beans) provided to respondents, only 11.8% of the sampled population are involved in just one, 14.3% engage in two, 31.2% engage in three, 26.1% engage in four and 16.6% engage in all five activities. They also cultivate on personal and consolidated farmlands.

The production of maize is in the range of 20-3000 kg and beans in the range of 10-1000 kg. This production quantity represents what is realised by the farmers after subtracting quantity lost. The quantity lost, both on the farm and out of farm, is captured separately. 92.5% of the maize farmers reported that they lost their maize during the last season while 80.6% of beans farmers experienced loss of their crop. The dairy farmers sampled reported they produce between 5- 60 litres of milk per day and lose between 1-25 litres of milk. *98.6%* of the farmers that lost their crops reported that it occurred on the field while *40.6%* of them reported that it occurred during harvesting or handling (drying, winnowing and storage). The major causes are drought, damage by pests and diseases, strong winds and inadequate postharvest handling and storage (PHHS) infrastructure. The most serious cause of the loss are pests and diseases.

We found that out of 299 members of the maize and beans farmers, 43.1% of them do not currently have drying facilities (which means they have to dry using tarpaulins or temporary hangers) and 56.9% responded that they do. Some 50.9% of those who have the drying facility do not use it at all. 63.2% of the dairy farmers experienced loss of their milk. The most serious cause of this loss has to do with milk handling equipment followed by transporting over long distance and milk handling skills. Only 48.5% of the dairy farmers use the milk cans while the rest use jerricans. This may prompt loss of dairy product since the jerricans cannot be cleaned easily leaving milk from previous use and contaminating their milk. Heavy weight of milk cans, ease of transporting and possibility of traveling with more litres of milk using jerricans, and high cost of milk cans compared to the plastic containers are reasons for the use of jerricans. Majority of the respondents (99.4%) access climate information mostly from radios and mobile phones. Only 24.7% of the respondents have adopted the use of irrigation system in case of droughts. The crop farmers stored 0 – 700 kg of maize and 0 – 500 kg of beans. The dairy farmers stored between 1- 8 litres of milk. For many of the cooperatives, it was learnt, they encourage their members to not sell what is left of their harvest in a season that they experience loss.

Using the USDA method for assessing food security, we found that 50% of the farmers are food secure; 16.3% are food insecure although without hunger and 33.7% are food insecure with hunger. While this figures may differ in a way from what is known of food security in Rwanda (In 2009, the World Food Programme had reported that 21% of Rwandans were food insecure, 22% in 2012 and 19.4% in 2015), it should not be seen as raising force alarms. This study is being carried out at a time after the most serious drought event in 60 years so a different figure like this is anticipated. It shows perhaps the impact of the drought resulting from climate change on food insecurity. Only few of the farmers have adopted irrigation facilities against flooding despite that the major cause loss is drought. Similarly, majority of the famers (80.6%) have not received training in non-agricultural activities and 85.9% of them have not received training on irrigation or natural resource management.

We conclude by saying that climate change is a multifaceted problem and will require multiple approaches to solve. Even though PASP may have achieved its aim to a large extent cutting postharvest losses as confirmed by the beneficiaries assessed, there is still a lot to do. Agricultural losses due to climate change is still a problem especially in Kayonza where drought events are witnessed. Perhaps this is why out of all the questions asked under the assessment of the project by beneficiaries, only the one on satisfaction on production level is widely rejected. Many of the farmers say they are not satisfied with the current quantity of production they end up with. This may be as a result of the quantity that they lose to drought. We advise that it is necessary to implement a project that focuses on finding alternatives to water needs of crops especially through irrigation.

CHAPTER ONE

INTRODUCTION

1.1 Background to the Study

Climate change and variability are emerging as major threats to development across the [African] continent and are impacting agriculture and livelihoods adversely (Bernard et al., 2015). Climate change results in different kinds of risks from physical impacts on (agro-)ecosystem, agricultural production, and food chains to economic and social impacts on livelihoods, income and trade, food security and nutrition (FAO, 2016a). Because of shifting rainfall pattern, farmers are unsure of when to plant or dry their produce. Sometimes they plant but rain does not come, and other times they plant and excess rain floods their farms. The gap period (of dry season) that some of the farmers use to dry their produce has now disappeared, making drying difficult and exposing harvests to risks of spoilage. Pests and diseases infestation are also a major risk to farmers productivity: both on farm and off-farm, pests and disease destroy crops leaving only little – if at all – for household consumption and sales. These conditions affect farmers' production and productivity and consequently impact food security, nutrition, economic prosperity and social wellbeing.

Sub-Saharan Africa is said to be the only developing region in the world where food insecurity has worsened in recent decades (Ringler et al., 2010 and FARA, 2014). Due to the limited economic development and institutional capacity, African countries are among the most vulnerable to the impacts of climate change (FARA, 2014). Yet Africa's population continues to grow at an estimated annual rate of 2.4%. The population is predicted to double its current 0.9 billion people by 2050. In order to feed this population, crop production will have to increase by 260% by 2050 (Bernard et al., 2015). To meet the Sustainable Development Goals on sustainable agriculture and food security by 2030 will mean having a system in place that is efficient enough to combat climate change. Africa's agriculture must undergo a significant transformation to be able to achieve food insecurity and significantly reduce poverty while also conscious of the environment.

Rwanda is largely an agrarian country with about 85% of the people living in rural areas. Although poverty is said to have declined from 57% in 2005 to 45% in 2011 (IFAD, 2013a), 43% of the country's population are in extreme poverty and 66% of the poor population reside in the rural areas (Msaki et al., 2015). Rwanda has the highest population density in Africa. Moreover, the country is characterised by agro-ecological diversity, with 12 agro-ecological zones (KIPPRA, 2017). The agricultural sector contributed 43% to the GDP in 2002, sustains 90% of the population (REMA, 2011 in Msaki et al., 2015), employs 80% of the labour force and is responsible for 45% of the country's export revenues (IFAD, 2013a). Agricultural production is predominantly at a subsistence level because a large number of rural household's farm plots are too small to support commercial production (KIPPRA, 2017). Since Rwanda's agriculture depends largely on the quality of rainfall, it is very vulnerable to the impacts of climate change. Also, the increased frequency of droughts period, floods, landslides and erosion that are observed considerably in the country decrease food productivity (REMA, 2011).

According to Rwanda's National Adaptation Programme of Action (2006), there are two major zones as regards vulnerability of climate change in the country: East/Southeast and North/Centre/West. The southern and eastern regions situated along Akagera and Akanyaru valleys are more sensitive to current climate variability and future climate change if observed tendencies continue. Despite that there is prolonged absence of precipitation leading to drought potential that cause negative effects such as drops in agricultural production, lack of water and food produce for the population, decrease of levels of lakes and rivers, lack of pastures for domesticated animals and soil and forest degradation in the region, people still migrate into these regions in search of new agricultural lands and pastures thereby presenting high economic and social vulnerability and putting more pressure on the natural capital. In the North and Centre/West however, the problem is high precipitation and landslides and landslips which increases the risk of floods, soil degradation and impoverishment, destruction of plants in swampy and river zones and destruction of infrastructure in low zones.

Africa technical and political leaders recognise the significance and need to address the issue of climate change and one of the ways as embedded in the Comprehensive Africa Agricultural Development Programme is "the adoption of Climate Smart Agriculture as a combined policy, technology and financing approach to achieve sustainable agricultural development under climate change" (Msaki et al., 2015). It is part of the Rwanda's Vision 2020 plan to triple agricultural production by 2020 and reduce the population depending on primary agricultural production to 50%. It is also part of the priorities of its Economic Development and Poverty Reduction Strategy II to achieve rural development, including agriculture modernization, environment and climate change between 2013 and 2018 (IFAD, 2013a). A joint study by the World Bank, Natural Resource Institute and Food and Agriculture Organisation cited in Stathers (2013) puts post-harvest losses of cereal grains in

Sub-Saharan Africa at nearly US$4 billion annually which is a 13.5% of the estimated US$27 billion value of annual cereal production in Africa. This annual cereal grain loss estimate equates average annual import of cereal in sub-Saharan Africa (which is between US$3 and 7 billion per annum) between 2000 and 2007 and is equivalent to annual caloric requirement of 48 million people at 2,500kcal per person per day (Stathers, 2013). One of the ways to address this for increased food production and security is through engagement in post-harvest activities such as drying, processing, storage and distribution to reduce post-harvest losses.

It is for this reason that the Climate Resilient Post-harvest and Agri-business Support Project (PASP) was initiated in March 2014. It is a five year project implemented by the Ministry of Agriculture and Animal Resources (MINAGRI) in Rwanda. It is co-financed by the International Fund for Agricultural Development (IFAD), the Government of Rwanda, commercial loans, as well contributions from project's beneficiaries and other value chain actors. It comprises the following three mutually reinforcing components:

i. HUB capacity development programme and business coaching;
ii. Post-harvest climate resilient agri-business investment support; and
iii. Project management and coordination.

The overall goal of the Climate-resilient Post-harvest Agribusiness Support Project (PASP) is to alleviate poverty, increase rural income and contribute to the overall economic development of Rwanda.

1.2 Problem Statement

While attention has been generally paid to on-farm crop intensification to address rural poverty and food insecurity, little effort has been made to increase crop productivity through the reduction of loss after harvest after food prices declined post 1970s food crisis. This means that even in the face of excellent crop and livestock pre-harvest practices, efforts may be thwarted by the challenges of post-harvest loss, especially in this era of serious climate change impacts, if efficient post-harvest technologies and management practices are not implemented. With dry spells, strong winds, fluctuating and heavy rainfall patterns threatening farmers' productivity, post-harvest reduction seem a way to consider to reduce food loss and food insecurity. To forestall this challenge, the International Fund for Agricultural Development, the government of Rwanda and other partners initiated PASP in

2014 to reduce rural poverty by reducing post-harvest losses and increasing smallholder farmers' income. In the light of this, this research work assesses PASP regarding its effectiveness in achieving food security and post-harvest loss reduction using three commodity value chains (maize, beans and milk) in Kayonza district as a case study.

1.3 Justification of Study

The overall goal of PASP is to reduce rural poverty, increase income and improve economic development of Rwanda by aggregating and adding value to CIP crops (maize, beans, cassava, and Irish potato) and dairy products and recently horticulture especially in this age of climate change. The project which began in March 2014 will reach completion in 2019. Assessing progress made so far especially in building resilience of smallholders to adapt to climate change impacts, improving rural food security and reducing post-harvest losses is critical. This study seeks to document the contribution of PASP in reducing agricultural production losses and food security. The lessons learnt from the results of this research can help guide future, similar projects to achieve maximum impacts.

1.4 Research Questions

The following research questions are to be answered through household-administered research questionnaires, focused group discussions and key informant interviews with farmer beneficiaries, cooperative management members and key staff of the implementation unit:

1. What are the socioeconomic and demographic characteristics of the smallholder PASP beneficiaries in Kayonza?
2. What are the current level and causes of post-harvest losses in Kayonza?
3. To what extent have the smallholder beneficiaries adopted post-harvest management and technologies?
4. What is the nature of food security of smallholder farmer beneficiaries at the household level?

1.5 Research objective.

The overall objective of this study is to assess the effect of PASP on postharvest losses and household food security in Kayonza district. The specific objectives are:

1. To identify the socioeconomic and demographic characteristics of the smallholder PASP beneficiaries.
2. To identify the current level and causes of post-harvest losses.
3. To evaluate the level of post-harvest management and technologies adoption.
4. To examine the level of household food security.

1.5.1 Analysis of Objectives

Table 1 Analysis of objectives

OBJECTIVES	DATA REQUIREMENT	SOURCE OF DATA	ANALYTICAL METHOD
Identify the socio-economic and demographic characteristics of the beneficiaries of PASP in Kayonza	Age, Gender, type of CIP crop grown, farm size, Family Size, number in the household, level of education, involvement in other economic activity than farming.	Primary data obtained from structured questionnaire Secondary data through literature review.	Descriptive statistics (measures of tendencies i.e. mean, median, mode, frequency distribution and cross-tabulation).
Identify the current level and causes of post-harvest losses.	Quantity of maize produced, quantity of beans produced, quantity of milk produced, stage of crop loss, causes of crop loss, causes of milk loss, container used for transportation of milk	Primary data (questionnaires and focused group discussion) Secondary data through literature review	Descriptive statistics (Frequency distribution, mean, percentages)
Evaluate the level of post-harvest management and technologies adoption.	Availability of drying and storage facilities, adoption of climate resilient technology on-farm and at household levels, access to climate information.	Primary data obtained from the use of questionnaire	Descriptive statistics (measures of tendencies i.e. mean, median and mode, frequency distribution, and percentage).
Examine the level of household food security.	Output, stored produce, family size, years of farming experience, access to PHHS	Primary data obtained from the use of questionnaire and	Descriptive Statistics, (frequencies, percentages, charts and cross tabulation, simple

	infrastructure, gender, and dependency ratio, adaptive capacity.	secondary data from previous work on food security	percentage, ratio, measure of central tendency & dispersion)

1.6 Definition of Key Terms

1.6.1 Climate Change. Climate encompasses the statistics of temperature, humidity, atmospheric pressure, wind, rainfall, atmospheric particle count and other meteorological elemental measurements in a given region over long periods. Unlike weather which is a measure of the atmospheric condition of a place over a short time, climate change is measured over a long period of time. The climate of a region functions by its climate system which has five components: atmosphere, hydrosphere, cryosphere, land surface, and biosphere. The more the quantity of greenhouse gases in the atmosphere, the more the amount of solar energy trapped by the planet which results in global warming or cooling (IPCC, 2007; Odoh and Chigozie, 2012). Climate changes are irreversible observable variations in the state of the climate over time; it is caused by two major factors: the natural process also known as bio-geographical and human activities also known as anthropogenic (IPCC, 2007). Through extreme weather events like increasing flood, increasing droughts, increasing winds and others, climate change impacts agricultural system causing impacts like reduction in yield and loss of agrobiodiversity and ecosystems services (FAO, 2016b). This will eventually lead to economic losses, social instability and food insecurity and hunger (figure 1).

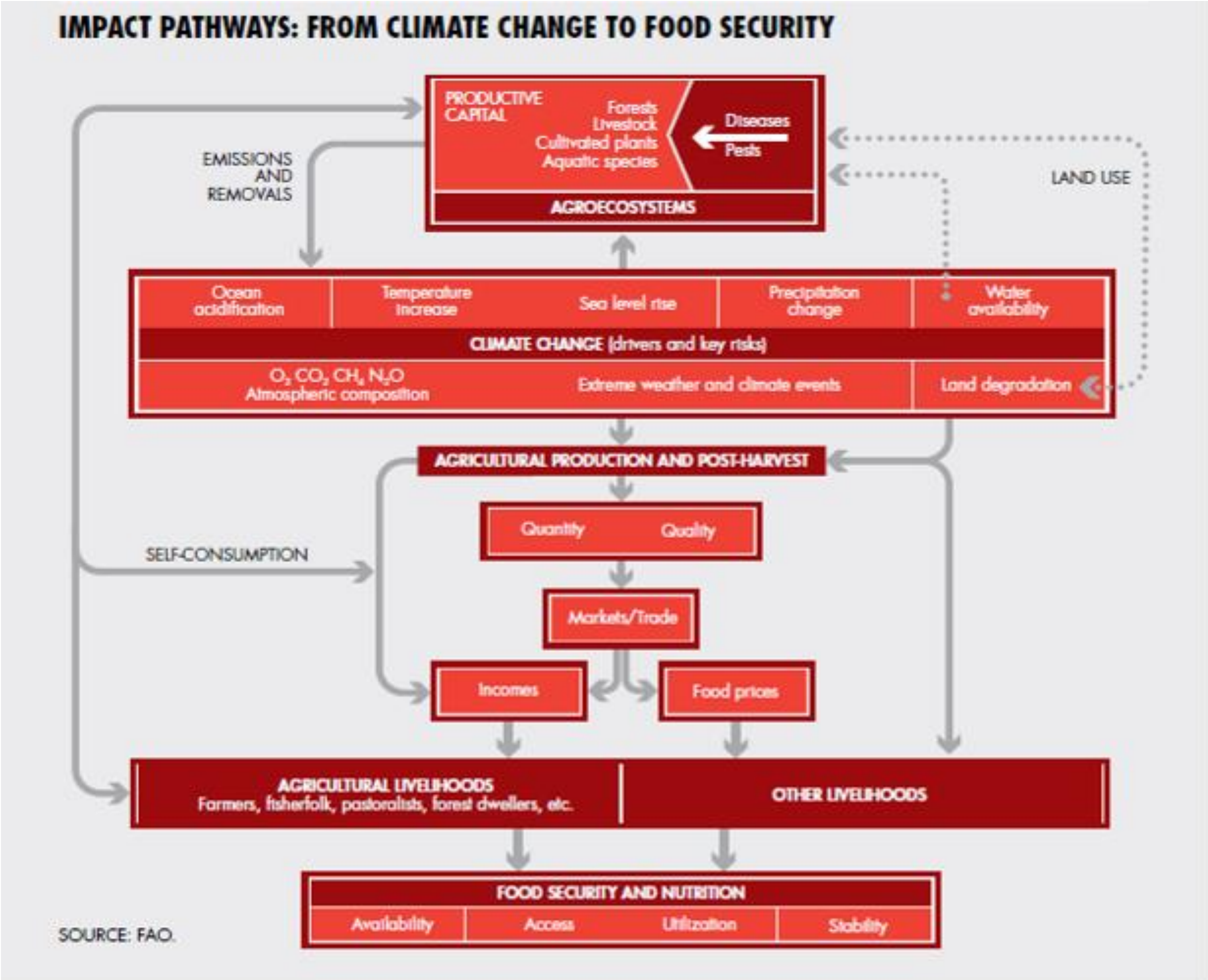

Figure 1 Pathway showing relationship between Climate Change Pathway, Agricultural Production and Food Security (Source: FAO, 2016b)

1.6.2 **Post-harvest losses.** Post-harvest systems involve the linkages that exist between (agricultural) producers and consumers and between rural areas and urban centres and the linkages with markets, technologies and organisations that make these linkages work (Stathers, 2013). Postharvest agricultural systems are diverse given the people, place, product and activity stages involved in this system. The crops go through different stages in the value chain after being harvested which are handled by different people in some cases. Crop postharvest systems can be divided into durables and perishables. The durables are the cereals and legumes that can be stored for months or years while the perishables are the (roots) and tubers and fruits and vegetables that cannot withstand such long period of storage as cereals and crops (Appert, 1987; Stathers, 2013) because of the higher moisture content and shorter shelf life. The period of drying an agricultural product depends on the "time of harvest, requirements of the other crops, labour availability for shelling, the time until the next rains, the moisture content of the grain at harvest and its drying rate" (Stathers, 2013). Given the incidence of climate change, farmers now find it difficult to dry their produce.

After drying, threshing/shelling is done by beating the cobs stored in a sack to release the grain or through a mechanical shelling device for larger crop quantities. Winnowing off of chaff or other unwanted materials could then be done. The next stage is to decide which protection (insecticide or repellent) will be used against insect damage during storage. In many cases where the length of storage is not intended to exceed three months, households do not treat their grains with protection against insect invasion (because damages caused by insects are still bearable until after four months) or they do so with "botanicals, sealed storage containers and customary rituals" in case the household cannot afford insecticides or repellents (Stathers, 2013). Through the PASP-ASAP collaborative funding, households are provided with hermetic bags to store their grains. These hermetic bags are airtight and hence extend crop shell-life during household storage. According to Stathers (2013), agricultural loss may be quantitative or qualitative and described in terms of the loss of the nutritive or economic value of the produce. Stathers further explained that it can also include "loss of: agricultural inputs, seed or grain viability and brewing ability, opportunity cost and goodwill."

1.6.3 Food Security. An expert working group of the American Institute of Nutrition in 1990 defined food security as "access by all people at all times to enough food for an active, healthy life. Food security includes at a minimum." According to this group of scientists, food security involves the "ready availability of nutritionally adequate and safe foods, and an assured ability to acquire acceptable foods in socially acceptable ways (e.g., without resorting to emergency food supplies, scavenging, stealing, or other coping strategies)." On the other hand, food insecurity means "limited or uncertain availability of nutritionally adequate and safe foods or limited or uncertain ability to acquire acceptable foods in socially acceptable ways." They defined hunger as "the uneasy or painful sensation caused by a lack of food" and could be a consequence of food insecurity. It should be noted that food insecurity and hunger referred to in this study does not mean or involve someone dieting or who is too busy to eat; it refers essentially to people or households that do not have food or money to procure food. Food security as also defined by the United Nations Food and Agriculture Organisation is a “situation that exists when all people, at all times, have physical, social, and economic access to sufficient, safe, and nutritious food that meets their dietary needs and food preferences for an active and healthy life.” (FAO, 2002; Stathers, 2013) and it has four key dimensions: availability, stability, access, and utilization.

1.7 Limitation of the study

While the PASP supports farmers growing maize, beans, cassava, Irish potato and horticultural products and dairy farmers, the focus of this study is only on beans, maize and milk. The study is also more interested in assessing postharvest losses, postharvest handling and storage infrastructure and food security than any other thing. This study has not separately quantified the losses made on the farm and those off-farm although it obtained that losses are made more on the farm than off-farm. It should also be noted that while PASP benefitted different kinds of players in the commodities value chains, the focus here was on the farmers.

CHAPTER TWO

THEORETICAL FRAMEWORK AND LITERATURE REVIEW

2.1 Review of Methodology

The United Nations World Food Programme in collaboration with Rwanda's Ministry of Agriculture and Animal Resources, National Institute of Statistics and other partners compute food security figures for the country. Since 2006 and every other three years, they adopt a Comprehensive Food Security and Vulnerability Analysis (CFSVA) and Nutrition Survey which uses a food consumption score to determine the households in the population that are food secure and those that are not. Households with poor of borderline food consumption are regarded as food insecure while those with acceptable food consumption are said to be food secure. In 2009, WFP reported that 21% of Rwandan households had unacceptable food consumption and hence were food insecure. Out of the 21% food insecure households, 4% of them had extremely insufficient and unbalanced food consumption and 17% had borderline food consumption. In 2012, 22% of the population were food insecure of which 3% were having extremely insufficient and unbalanced diet and 19% on the border line. In 2015, WFP reported Rwanda's food security in a newly formulated CARI food security console which divided the population into four groups based on food security: 40% of the households were food secure, 40.2% marginally food secure, 16.8% moderately food insecure and 2.6% severely food insecure (WFP 2012, 2015).

For this current study, the food security measure was adopted from the United States Department of Agriculture (USDA, 2000). According to this guide, "traditional income and poverty measures do not provide clear information about food security, even though food insecurity and hunger stem from constrained financial resources." It also noted that household food insecurity and hunger cannot be captured by a single indicator, but through obtaining information on different specific conditions, experiences, and behaviours. These kinds of conditions, experiences and behaviours are captured in the following and form the basis of the questions asked (see Appendix 1) to determine food insecurity and hunger of households:

- Anxiety that the household food budget or food supply may be insufficient to meet basic needs;
- The experience of running out of food, without money to obtain more;

- Perceptions by the respondent that the food eaten by household members was inadequate in quality or quantity;
- Adjustments to normal food use, substituting fewer and cheaper foods than usual;
- Instances of reduced food intake by adults in the household, or consequences of reduced intake such as the physical sensation of hunger or loss of weight; and
- Instances of reduced food intake, or consequences of reduced intake, for children in the household (See Appendix 1 under food security at household level for list of the questions).

In the original USDA Food Security Scale, there are 15 questions with 3 follow up questions to make 18 in all. Responses to the 18 set of questions are analysed as in Box 1 above. For the first category i.e. the households without children: those that respond affirmatively to 0-2 items are considered food secure; those who respond affirmatively to 3-5 questions are food insecure but without hunger while those who respond affirmatively to 6 or more are food insecure with hunger (USDA 2000). According to scale, the households considered food insecure with hunger can be divided into two: moderate and severe based on whether or not children in the household are included in those who have reduced food consumption and felt hunger. This method of measuring household food security is not without its limitations. First, the focus of the questions is whether a household has enough food or money to acquire food; the questions do not consider other aspects of food security like food safety, nutritional quality of food, and social acceptability of food sources etc. Secondly, other sources of food insecurity beyond the constraint of finance are not covered. Despite this, the scale is simple to estimate and still relevant in measuring food security.

Box 1 Categorisation of Food Security according to USDA (2000); Nord et al. (2005) - Original Scale

Categorization of Food Security Status of Households According to the Number of Affirmed Items on the Food Security Scale

1. *Households without children (based on responses to the 10 adult and household items):*

Food secure = households that denied all items or affirmed 1 or 2 items

Food insecure without hunger = households that affirmed 3, 4, or 5 items

Food insecure with hunger = households that affirmed 6 or more items

2. *Households with children (based on responses to all 18 items):*

Food secure = households that denied all items or affirmed 1 or 2 items

Food insecure without hunger = households that affirmed 3 to 7 items

Food insecure with hunger = households that affirmed 8 or more items

In the current study, the questions were modified and expanded from 18 to 22 for easy coding in SPSS. For the questions in the original scale that included more than two options (such as those with Never true, Sometimes and Often), they were first recoded as a YES (for those who chose "sometimes" or "often")/NO (for those who chose "never true") question then a follow up to separate "sometimes" and "often" for those coded as "YES". Similarly, questions that included follow up questions like "almost every month, some months but not every month, or in only one or two months" are simplified into often and sometimes, again for easy coding in SPSS. Having done this, we ended up with 22 questions. This also meant that the scale of analysing had to change. The new scale developed is shown in Box 2 below.

Box 2 Modified categorisation of Food Security adapted from USDA (2000); Nord et al. (2005)

Categorization of Food Security Status of Households According to the Number of Affirmed Items on the Food Security Scale (Modified)

3. *Households without children (based on responses to the 11 adult and household items):*

Food secure = households that denied all items or affirmed 1 to 3 items

Food insecure without hunger = households that affirmed 4 to 6 items

Food insecure with hunger = households that affirmed 7 or more items

4. *Households with children (based on responses to all 22 items):*

Food secure = households that denied all items or affirmed 1 to 4 items

Food insecure without hunger = households that affirmed 5 to 9 items

Food insecure with hunger = households that affirmed 10 or more items

2.2 Review of Empirical Studies

2.2.1 Climate Change

Sub-Saharan Africa is characterised by smallholder, rain-fed agriculture (especially cereal grains which are the staple foods) and is vulnerable to climate change impacts given socioeconomic and biophysical factors which limits the region's capacity to adapt to climate change impacts (Stathers, 2013). Stathers suggests that in the tropics yield of many crops will decline and some of the areas of land will become uncultivable due to climate change. With this could come as much as 50% reduction in yield in some areas by 2020 and 90% in net revenues by 2100 (Stern, 2006 and Boko et al., 2007 in Stathers, 2013; World Bank, 2014) thereby increasing the need to import cereal products to meet food demand (Fischer et al. 2005; Cline 2007; Schmidhuber and Tubiello 2007) or the need to expand the current area of land under cultivation which is not sustainable. Land expansion, according to Stathers, occurs at the expense of natural vegetation and could further intensify global warming.

The table below are two of the five climate change trends (the other three being more frequent occurrence of high winds, storms, heavy precipitation events and flooding; more erratic rainfall; and increased rainfall amount and/or duration) considered by Stathers (2013) and how they affect activities, assets and human wellbeing. Stathers stated that while these trends were explained independently, some regions will experience a combination of them which will increase their vulnerability. He suggested some adaptation opportunities that have been promoted and practised in postharvest agriculture and the ways to take advantage of these opportunities. Luckily, many of the postharvest adaptation opportunities proposed applies to several climate change trends. For example, by treating all grains to be stored beyond three months with the appropriate protectant or using hermetically sealed containers, pests and diseases will be controlled which translates to less vulnerability to the impacts of increased temperature; frequent occurrence of dry spells and droughts; frequent high winds, storm, heavy precipitation events and flooding; erratic rainfall; increased rainfall or amount and/or duration.

Table 2 Possible effects of different climate change trends on postharvest systems of durable crops in east and southern Africa (Source Stathers, 2013) [key for the human wellbeing outcome: H=Household level; L=Local level; N=National level; G=Global level]

A. GENERAL INCREASE IN TEMPERATURE		
Impact on postharvest activities	Impact on rural households postharvest assets	Impacts on human wellbeing outcomes
On harvesting and drying: • Increased rate of crop drying in the field and at homestead • Increased fire risk for mature crops ***Primary processing:*** Heat stress during laborious primary activities (shelling/threshing; dehuling) ***Pest and diseases management:*** • Faster reproduction of insect pests and diseases (shorter lifecycles due to higher temperatures) lead to build up of insects and fungi in stored produce • Increased risk of fungal rot and mycotoxin contamination • Pest and diseases territories expand • Decrease in efficacy of some grain active ingredient and increase in	***Human:*** • Reduction in labour productivity and diet quality and increased health risks • Traditional postharvest knowledge and skills become less effective due to changing climates ***Natural:*** • Deterioration of stored products • Loss of crop	***Food security:*** • Quality and quantity of food reduces due to loss and damage [H,L,N] • Dependence on non-self-produced [H,L] and imported [N] food will increase • Higher food price and reduced labour productivity reduces the ability of poor people to access nutritious food [H,L,N] • Health status and productivity reduces

others ***Storing:*** • Higher pest incidence and the need for managing previous infestation before new storage • Increased pest reproduction and mobility necessitating re-winnowing, sorting and retreating grains • Increased moisture migration and condensation leading to excess free moisture • Increased risk of seed viability damage ***Secondary processing:*** • Increased risk of bio-deterioration leading to products with shorter shelf-life • Overheating of machinery leading to low profits ***Transporting:*** • Heat stress (for humans, animals and vehicles) ***Marketing:*** • Increased crop failures gives producers and traders from areas of surplus new market opportunities • Increased phytosanitary requirements for cross-border trades ***Utilisation:*** • Greater insect damage leads to increased need to sort grains before use as food • Increased food safety concern	biodiversity ***Physical:*** • Due to loss of bio-resources, constructing traditional drying platforms becomes difficult. ***Social:*** • Prices of stored products increase • Increased need for postharvest storage and market information • Seasonal price increase makes traders to store more ***Financial:*** • Prices of stored products increase • Increase in pest and diseases and waste of prepared food will increase expenditure	[H,L,N] ***Social:*** • Increased abusive behaviour (alcohol, domestic violence) in response to crisis [H, L] • Family breakdown due to temporary and permanent labour migration [H, L] • Decreased investment in human capital (e.g. education) [H, L, N, G] • Reduced self-esteem, independence or human dignity associated with food aid [H, L, N] ***Financial:*** • Cost of food relief and safety net programmes increase [L,N, G] • Use of resources meant for long-term needs to meet emergency short term needs [L,N,G] • Rise in import bill [N]
B. MORE FREQUENT OCCURRENCE OF DRY SPELLS AND DROUGHTS		
Harvesting and drying: • Increased variability of crop yield • Crops dry faster on the field which reduces the rate of attack by pest on the field • Crops dry faster at the homestead ***Primary processing:*** • Smaller and shrivelled grains that are hard to sell. ***Pests and diseases management:*** • Less chance of an increase in postharvest pest population • Pest outbreaks in some new	Human: • Labour becomes less productive due to poor diet; labour demands change • Household labour reduced due to migration • Traditional postharvest knowledge becomes less applicable.	***Food and water security:*** • More people exposed to water scarcity [L, N, G] • Food supply becomes more unpredictable • Lower quality diet [H, L] • Food importation and need for food relief [N] • Vulnerable women,

geographical areas ***Storing:*** • Increased crop failure and need for seed for replanting • Difficulty in predicting duration of storage and food quantities required • Increase in secretive storage practices • Increased human contact with storage pesticides • Rodent-borne diseases risks increase ***Secondary processing:*** • Availability of raw materials reduce leading to increase in their price. ***Transporting:*** • More transport activity due to rise in food scarcity ***Marketing:*** • Inter-seasonal price variations and high prices results from crop shortage • Smallholder farmers increasingly tempted to sell more of their food crops. ***Utilisation:*** • Scarcity of clean water for food preparation • Extra time spent searching wild food alternatives	***Natural:*** • Crop varieties suitable for cultivation changes • Loss of crop biodiversity, grazing lands and fuel wood • Shortage of water and fuel for food preparation. Physical: • Emergency sale of assets • Frequent fire outbreaks destroying properties • Biodiversity loss ***Social:*** • Increased demand for food safety net. • Dependence on external social protection ***Financial:*** • Increase in the value of stored produce • Variation in income from crop sale • Possible loss due to theft	orphans and elderly feel the impact more [H, L, N] • Food stock reduces [H, L] ***Social:*** • Sale of productive asset [H] • Increased request for food from neighbours and relatives [H, L] • Abusive behaviours (alcohol, witchcraft, domestic violence) as a response to crisis [H, L] • Decrease in human capital development • Family breakdown due to migration ***Financial and economic:*** • Cost of food relief and safety net programmes increase • Farm income reduces and competition for off-farm employment rises • Use of resources meant for long-term needs to meet emergency short term needs [L,N,G]

2.2.2 Food Security

The World Bank in 2014 estimated that 37% percent of food produced is lost and wasted. As many as 550 million additional people could go hungry globally if population rise and disparities in income continues by 2080. Africa will account for 65% of the global climate related hunger by 2050 (Easterling et al., 2007 and Parry et al., 2009 cited in Stathers, 2013) meaning that the chance of achieving the goals and commitments to end hunger by 2030 is currently bleak. As climate change reduces the yield of commodities and increases their value, postharvest loss will only further increase the value of these commodities. The solution to this challenge is not in increasing production (as this will waste limited natural resources), but efficient postharvest handling and management which reduces postharvest losses and ensures that poor people have access to cheap and safe foods (World Bank et al., 2011; Stathers, 2013). Households may shift to taking cheaper staples with vegetables during the hungry months before harvest, reduce the size of their meals or number of times they take meals daily (Manda and Muveni, 2010; Stathers, 2013) which may cause food insecurity and malnutrition.

2.2.3 Post-harvest Losses

Smallholder farmers harvest, dry and store their farm produce for household consumption till their next harvest. Some of the stocks are sold for the purpose of generating income for the household. But during these post-harvest periods, the farm produce suffer some loss as a result of pests and diseases infestation, spoilage, damage during transportation and market weaknesses. These losses become more pronounced given climate change and variability (Stathers, 2013). According to Stathers, staple food crops are transported after harvesting using head-load, bicycle or carts to where it will be dried. The drying facility may include a raised platform constructed from "poles and the stalks of the crops, thatch grass or wire" or "rooftops, floors or specially prepared ground surfaces. There are however new specifications for climate-smart drying facilities, for example the one prescribed by the Adaptation for Smallholder Agriculture (ASAP). This includes a drying ground of 25m×5m (12.5m×10m) area; a shed of 20×10m×4.5m; 12m^2 drying mesh; 4m×10m equipment store or temporary grain store; modern toilets; and retainer wall with the installation of two 5,000Lof rainwater tanks for rainwater harvesting, overflow soak away to control drainage, and solar PV installation with inverter to provide renewable energy (Rugege, D and Vermeulen, S. (2017).

Traditionally, communities collectively store their cereals in grain banks as a form of food security strategy, but this usually faces problem in the presence of external influence. Insects can cause as much as 30% weight loss during storage depending on the insect, their population density and environmental conditions. Fungal growth also occurs in grains that have been stored without properly drying or in grains where insect damages have increased moisture content. Fungal growth in grains is dangerous as it can result in "spoilage, reduced germination, discolouration, caking, mouldy smells and may produce toxins (mycotoxins) which can result in health problems and even death (WHO, 2006 and Wagacha and Muthomi, 2008 cited in Stathers, 2013). Table 3 shows the maximum moisture content preferred for long term storage for different crops.

Table 3 Maximum moisture content for long term storage of different commodities (Source: Appert, 1987 cited in Stathers, 2013)

Moisture content	**7%**	**8%**	**9%**	**10%**	**11%**	**12%**	**13%**	**14%**	**15%**	**16%**
Crop	Ground nuts					Sorghum (12.5%)	Maize Rice Wheat	Paddy	Legume	Millet

During storage, different kinds of management strategies such as drying/moisture content reduction, heat treatment, grain cooling, and aeration are put in place so that pests are no longer able to feed or breed and biological deterioration are put under control. In the tropics, sun drying is used by small-scale farmers to raise temperature to a point where storage pests are unlikely to survive while in higher latitude areas cooling of grain is done on a large scale so that the temperature reaches a point where the pests are unable to reproduce or attack the stored grains (Dobie et al., 1985 Fields, 1992; Stathers, 2013). In addition, unpredictable climate makes drying difficult for farmers as, in the case of Rwanda, the two seasons of rain, are almost undistinguishable. A good storage practice for grains involve taking adequate measures against moisture, rodents, birds and thieves and making sure that the condition is not suitable for deterioration. By drying and storing at a cool temperature (less than 14^{o}C moisture content) in airtight/hermetic bags, grains can be prevented from deterioration (Stathers, 2013) especially if the drying is done to a moisture content low enough to not accommodate metabolism of pests (see Table 1).

2.2.4 Post-harvest Handling and Storage Infrastructure

Rugege and Vermeulen (2017) carried out a study assessing the intermediate results of the ASAP investments in weather information, trials of climate-adapted maize and forage crops and climate-resilient infrastructure as contained in PASP's Components 1 and 2. Their study however did not relate these results to household food security. Their work on the assessment of access to climate information services showed that majority of the interviewed farmers and their cooperative leaders access weather information more through radio and/or TV and seasonal climate advisory information through physical meetings and institutional officials as wells as radio than they do on their mobile phones. Also while the farmers use weather information and climate advisories to plan their farming operations (including post-harvest activities), some of them consider daily weather information not as helpful to their post-harvest activities (even though they used it to plan drying) as is forecast over period of days.

Rugege and Vermeulen (2017) confirms that ASAP has provided funds through PASP to Rwanda Meteorological Agency, Rwanda Agricultural Board among others to support smallholder farmers to adapt to climate change impacts. The meteorological agency is strengthening its capacity on weather data collection to meet the specific needs of the 12 districts where PASP operate. To achieve this purpose the agency conducted microclimatic studies in 5 of the 12 districts to enable it disseminate early warnings on climate risks and vulnerabilities such as "quantity of rainfall, length of the rainy and dry seasons, wind directions and sunrise and sunset times." On the other hand, the Rwandan Agricultural Board working with the Single Project Implementation Unit (SPIU), the unit that is implementing PASP, is using an Agricultural Production System Simulator (APSIM) to run forecasts on the yields of varieties of maize and potato. Training on weather information packages have been provided to HUB users in almost half of the PASP intervention districts – in the northern and southern provinces – as well as training on climate risk management provided to over 720 farmers from over 120 cooperatives. Through research collaboration between PASP and Rwanda Agricultural Board, crop and forage varieties that mature early and are more resistant to flood and droughts are developed. According to an ASAP-Rwanda (2016) Working Document, 5 new varieties of maize were released in (growing) Season B of the year for multiplication and 7 other varieties were being assessed.

According to an assessment done by Bendito and Twomlow (2015) and quoted in Rugege and Vermeulen (2017), "almost all rural post-harvest and storage infrastructure in Rwanda did not comply with the basic guidelines for climate resilience, demonstrating high vulnerability in the face of imminent effects of climate change" and putting post-harvest loss figure at an estimated 30%. To address these challenge of post-harvest loss, climate smart technologies such as "hermetically sealed grain storage bags, multi-purpose tarpaulins, silage bags, perforated packaging crates, net bags, solar bubble dryers and rainwater harvesting" are provided to farmers in the 12 PASP-ASAP intervention districts. Quoting a 2016 IFAD Working Document, Rugege and Vermeulen (2017) noted that 100,500 hermetic bags and 9,848 tarpaulins (plastic sheets) have been provided for distribution among cooperative members. Of these, 10,500 hermetic bags and 1,140 tarpaulins had been distributed within the 12 intervention districts. Based on a final distribution list obtained from the SPIU, a total of 10,000 hermetically-sealed bags have now been distributed to 3,401 beneficiaries in Kayonza District alone. Accordingly, 1000 tarpaulins have been distributed to 16 cooperatives in Kayonza District (7 of these cooperatives are among those sampled for this study). The IFAD Mid Term Review document noted that due to the capacitation of farmer cooperatives with postharvest management and infrastructure, they have been able to reduce postharvest losses, increased and increased their income.

Rugege and Vermeulen (2016) assessed the pilot drying hangers and warehouses in the Eastern Province and found that the facilities complied with the minimum requirements for design, construction and material use. The structures had in them features which could withstand extreme weather events such as the "structure height, width, slope and pitch of the roof, distance between each column and roofing truss, width of roof overhang, thickness of floor slab and rainwater management systems." Because the facilities were constructed using metallic materials, burnt bricks and concrete, the risk of termites eating up wood is addressed. The warehouses assessed had roof cyclofan turbines and side wall vents to control the storage's humidity. There were photovoltaic solar installations in the facilities used for lighting and charging and rain water harvesting systems for drinking, crop processing and cleaning activities. Similar observations were made in the cooperatives visited that have built their drying facilities and warehouses. In addition, the structures were raised enough aboveground such that floods would not enter into these facilities.

CHAPTER THREE

METHODOLOGY

3.1 Study Area

The study area chosen is Kayonza district in the eastern province due to its peculiarity to climate change especially drought events. The population of Kayonza according to the Rwanda National Institute of Statistics is 332,000 (NISR, 2011). The district is characterised by two principal seasons: a long period of dryness and a short one of rain. In 2016 and some early part of 2017, the district faced what the Ministry of Agriculture and Animal Resources regarded as the worst drought in 60 years affecting crops planted on 16,119 hectares of land.[1] Out of the 12 sectors in the district, a total of seven were chosen for the study (Gahini, Kabarondo, Mukarange Murama, Murundi Mwiri, Nyamirama). A total of thirteen (13) cooperatives (10 crop and 3 dairy) were visited within seven sectors: Abajeneza, Abanyamurava Nyamirama, Abizeranye, Dufatiyambere Mu Mihigo, GAFCO, Giramata, Karambo 1, Koaimu, MUFCOS, Muryawetu, Twidika, Twisungane Migera, Twitezimbere Nya.

[1] Ministry of Agriculture and Animal Resources - Government Commits to Sustainably Tackle Climate Change Effects on Agriculture (http://www.minagri.gov.rw/index.php?id=469&L=1For&tx_ttnews%5Btt_news%5d=1323&cHash=06fe0d081757e834b71d3831cadca - Accessed Online on June 27, 2018)

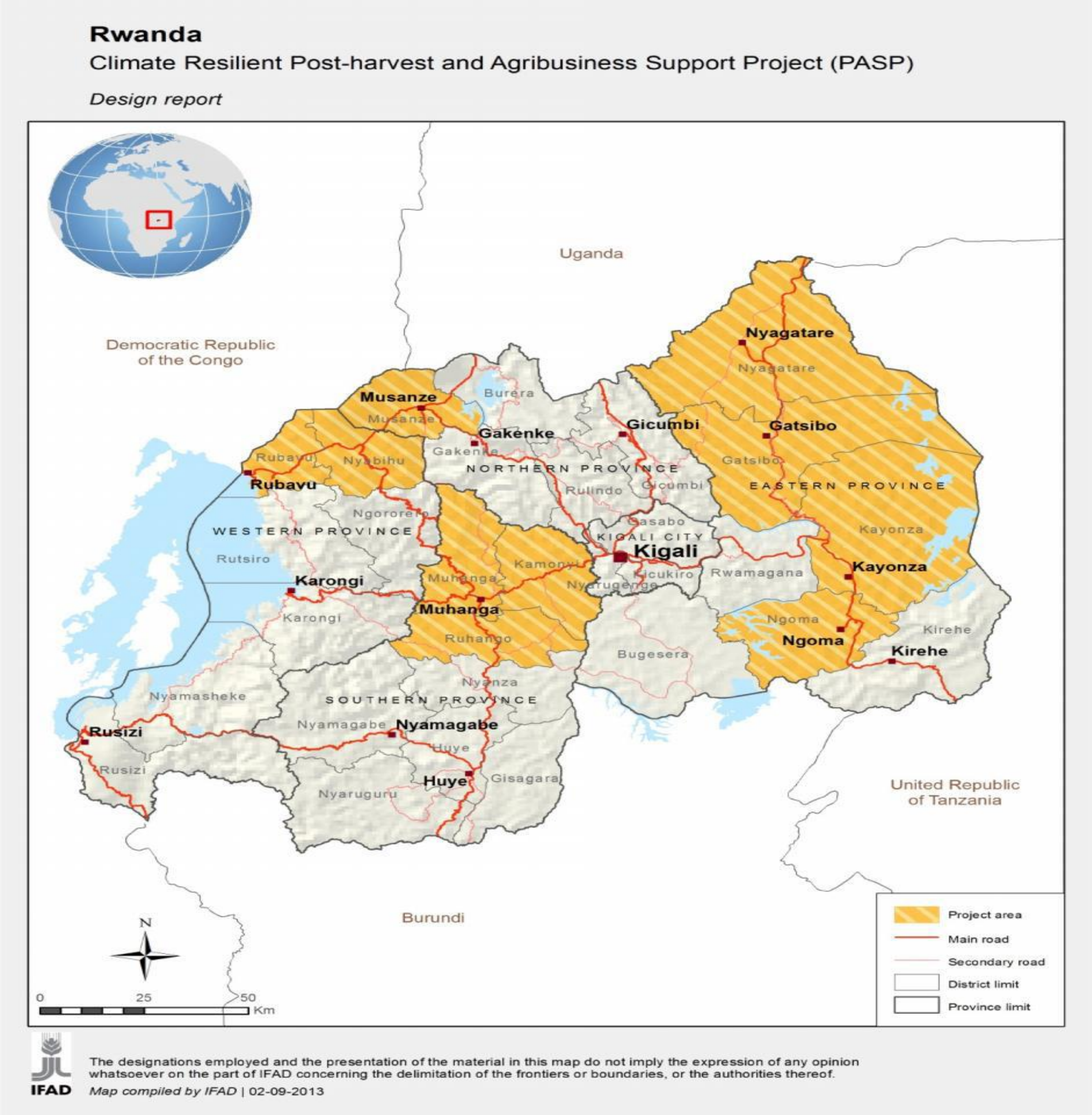

Figure 2 Map of Rwanda showing the district areas of operation of PASP (Source: IFAD, 2013b)

3.2 Data and Sources

The study shall use both primary and secondary data. Primary data shall be sourced from the administration of structured questionnaires and focus group discussions with smallholder farmers who are beneficiaries of the PASP, and key informant interviews with SPIU staff members. Secondary data shall be sourced from baseline and impact studies, working papers, project reports and other relevant documents.

3.3 Sampling Method

The sampling method to be used is multistage sampling: the sample district was purposively chosen from a list of twelve beneficiary districts followed by a cluster sampling of the cooperatives that have benefitted from PASP in the district. From this list of cooperatives, 10 maize and beans and 3 diary cooperatives were randomly picked.

3.4 Analytical Techniques

The analytical techniques used for this study is descriptive statistics (frequency count, tables, charts, percentages etc.)

CHAPTER FOUR

RESULTS AND DISCUSSION

4.1 Socioeconomic and Demographic Characteristics

Three hundred and fifty-six (356) farmers in Kayonza district were sampled using a well-structured questionnaire (Appendix 1). Out of these cooperative members, 57 were from dairy cooperatives and the rest 299 were farmers in maize and beans cooperatives (See Table 4 below). The household size of the respondents ranges from 1 to 12 members with an average of 5.3 which is modestly close to 4.7 reported by the country's institute of statistics (NISR, 2011). It is interesting to note that one hundred and eighty-one (equivalent to 51%) of the respondents are females. On the age of the farmers, majority (46.9%) belong to the 31-45 years age bracket followed by 46-60 years age bracket (29.2%) and above 60 years (12.1%) before the 15-30 years age bracket (11.8%) (See fig. 4 for details). The literature establishes however is that the average age of farmers in Rwanda is 55 years.

Table 4 Distribution of farmers into dairy and crop cooperatives

	Cooperative type and number sampled		**Total**
	Dairy Cooperative	Crop Cooperative	
Abajeneza	0	18	18
Abanyamurava Nyamirama	0	19	19
Abizeranye	0	29	29
Dufatiyambere Mu Mihigo	0	21	21
GAFCO	21	0	21
Giramata	16	0	16
Karambo 1	0	20	20
Koaimu	0	46	46
MUFCOS	20	0	20
Muryawetu	0	12	12
Twidika	0	83	83
Twisungane Migera	0	31	31
Twitezimbere Nya	0	20	20
Total	57	299	356

On marital status of the farmers, majority of them (82.9%) are married while 3.1% are divorced, 3.4% single and 10.7% widows. Out of 335 respondents to the land size question, only 7.5% own land that is over 2 ha in size; 9.3% own between 1 and 2 ha of land; 45.6% have between 0.5 and 1 ha and 37.6% own less than 0.5 ha of land meaning that they cultivate on small areas of land. It means that majority of the farmers are between very small cultivators (under 0.3 ha) and medium cultivators (0.9 to 3.0 ha) according to NISR (2011).

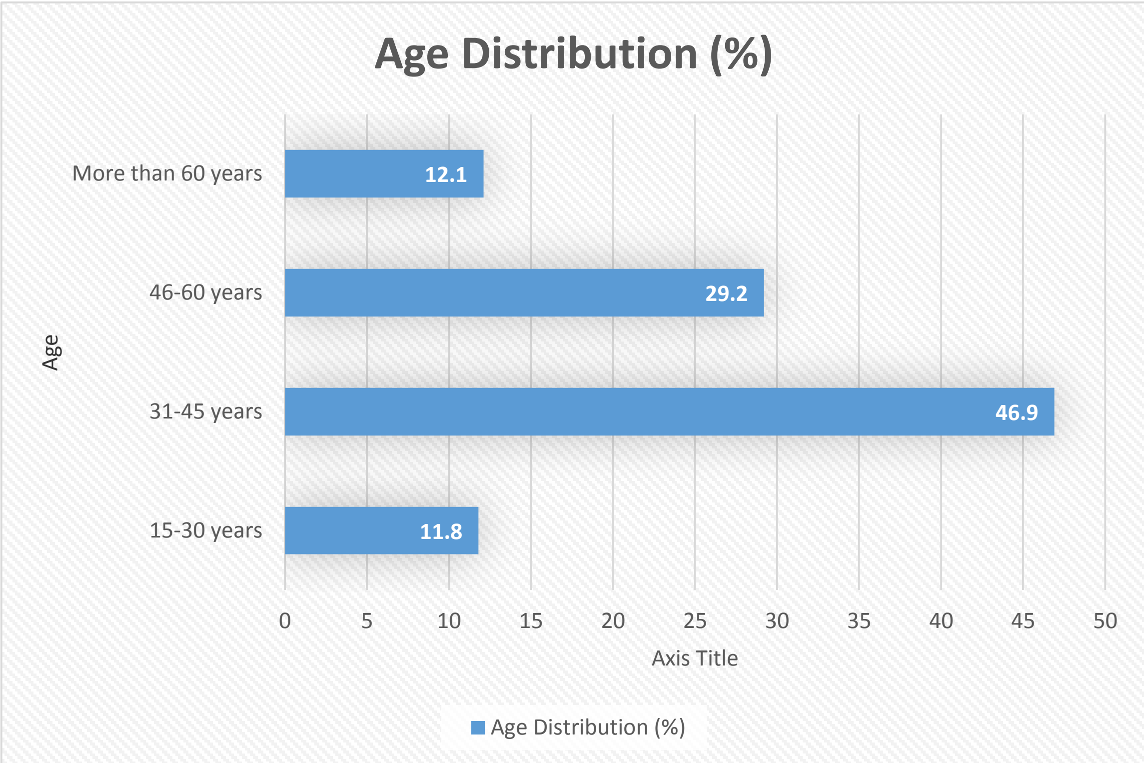

Figure 3 Age distribution of farmers in Kayonza District

When land size is separated by gender, it becomes clear that females own smaller lands than male: the females own more of the less than 0.5 ha and between 0.5 and 1 ha while the males own more of 1-2 ha and greater than 2 ha lands (see figure 5). The dairy farmers have between 2 and 30 cows and produce between 5 and 60 litres of milk per day.

On education, majority of the farmers (62.9%) only have primary education, 21.9% don't have formal education, 13.2% have secondary education, 1.7% have high school education and only 0.3% have higher institution education. Analysing this response by gender, more females have no formal education, more males have primary education, more females have junior high school education, more males have higher school education and the only respondent with university education is male.

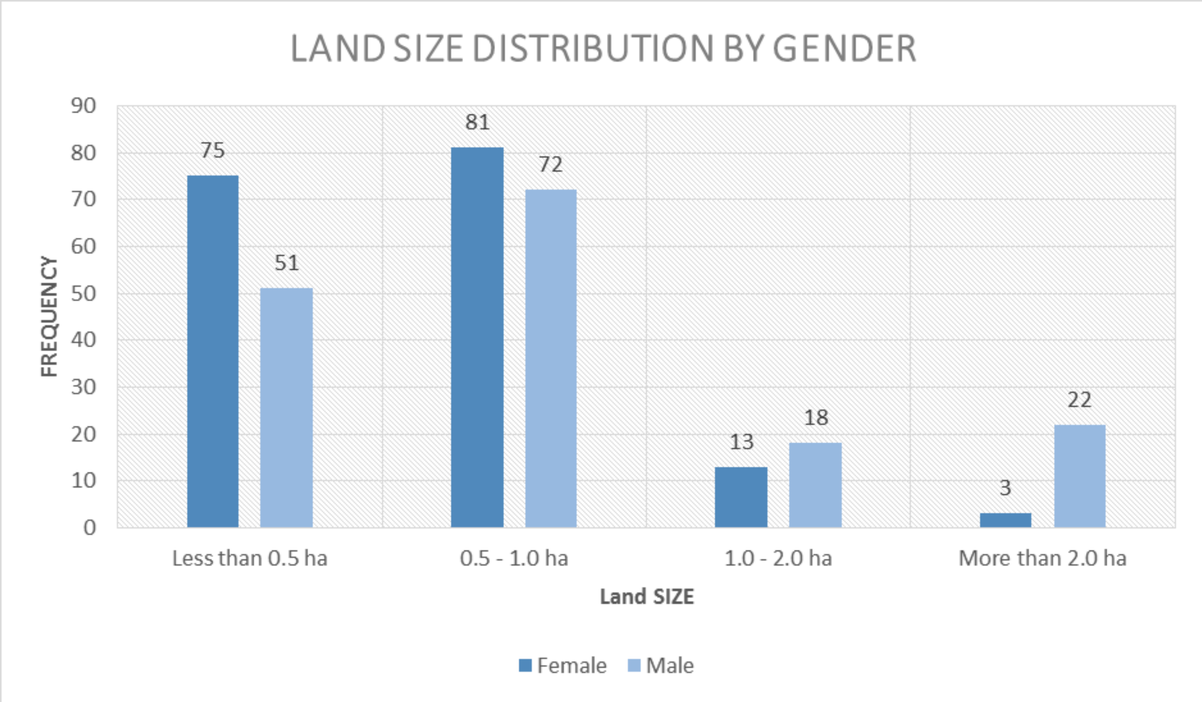

Figure 4 Size of land owned by the farmers

Majority of the farmers (88.2%) depend solely on farming as their source of income while only 11.8% engage in other economic activities not related to farming. In spite of this, many of the farmers diversify their agricultural production. The farmers were asked which of five groups of agricultural activities (growing maize, growing beans, rearing cows, rearing small domestic animals like goals, fowls and pigs, and growing other crops than maize and beans) they are involved in: only 11.8% of the sampled population are involved in just one of the five groups of agricultural activity, 14.3% engage in two, 31.2% engage in three, 26.1% engage in four and 16.6% engage in all five activities (figure 6).

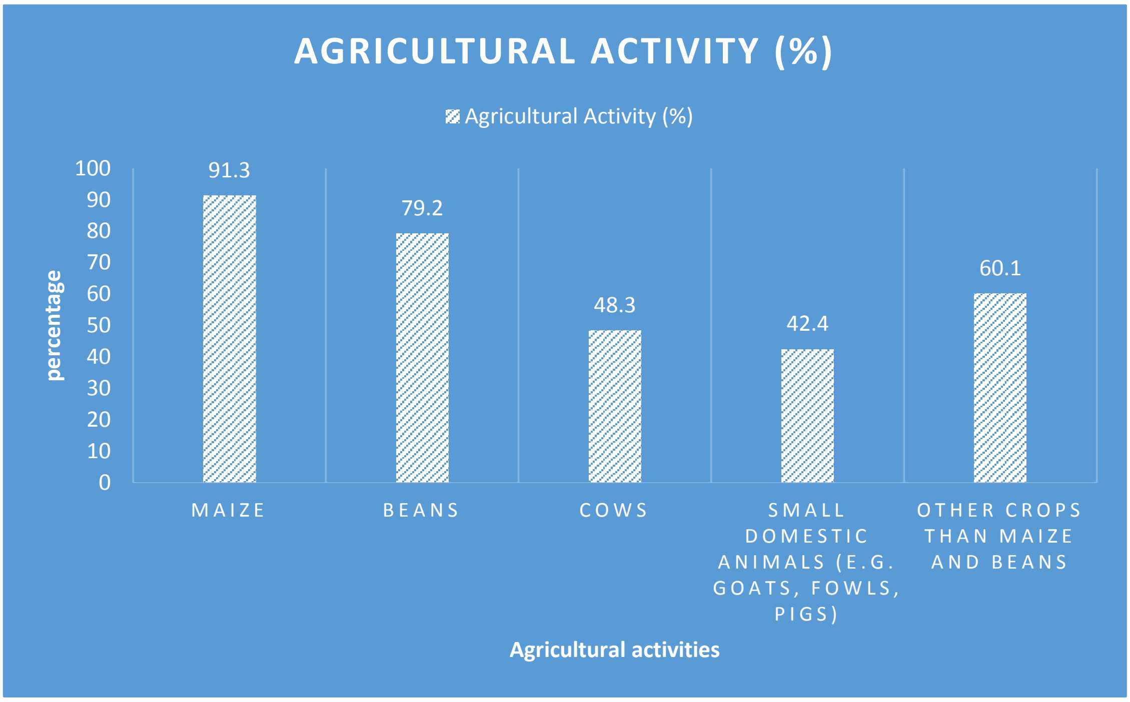

Figure 5 Different agricultural activities engaged in by the farmers

4.2 Level and Causes of Post-harvest Losses

The farmers were asked to state the quantity of their production and if they experienced loss, quantify it. The production of maize is in the range of 20-3000 kg and beans in the range of 10-1000 kg on the size of land reported earlier. It should be noted that the production quantified here is the one realised in the end by the farmers (sold or kept for household consumption) and does not include the quantity lost. The quantity lost, both on the farm and out of farm, is captured separately. Out of the two hundred and ninety-four (294) farmers from the maize and beans PASP-supported cooperatives that grow maize, 92.5% of them reported that they lost their maize during the last season while out of the two hundred and fifty-two (252) farmers that grow beans, 80.6% of them experienced loss of the crop. The dairy farmers sampled reported they produce between 5- 60 litres of milk per day and lose between 1-25 litres of milk (see Table 5 below).

Table 5 Quantities of production and loss for maize, beans and milk among the members of the farmer cooperatives

	Minimum	*Maximum*	*Median*
Quantity of Maize produced (kg)	20	3000	250.0
Quantity of Beans produced (kg)	10	1000	100.0
Number of cow owned (kg)	2	30	8.0
Quantity of Milk produced (litres)	5	60	12.0
Quantity of Maize lost (kg)	15	1500	153.5
Quantity of Beans lost (kg)	5	600	100.0
Quantity of milk lost (litres)	1	25	4.5

Two hundred and eighty-three farmers who reported loss of their beans and/or maize were asked to state the stage at which the losses occurred: *98.6%* of them reported that it occurred on the field while *40.6%* of them reported that it occurred during harvesting or handling (drying, winnowing and storage). This means that the farmers experience the losses at both on-farm and off-farm although it is clear that they lose more on the field than during/after harvesting. The following reasons may account for the loss: when the farmers were presented with some factors (as stated in Table 6 below), the major causes are drought, damage by pests and diseases, strong winds and inadequate postharvest handling and storage (PHHS) infrastructure. The most serious cause of the loss are pests and diseases: 60.1% of the respondents regard these as a very serious problem, 32.2% regard it as a moderate problem and only 7.8% think it is not a problem (Table 6).

Table 6 Factors responsible for crop loss

	Drought through frequent dry spells	**Damage by pests & diseases at farm**	**Strong winds affecting both farms and PHHS infrastructures**	**No adequate PHHS equipment/ infrastructure**	**No adequate transport**	**Lack of market access**	**Flooding of farms**
Not a Problem	31.8%	7.8%	63.3%	58.7%	94.7%	88.0%	88.3%
Moderate	13.1%	32.2%	12.7%	37.1%	4.6%	8.8%	8.8%
Very Serious	55.1%	60.1%	24.0%	4.2%	0.7%	3.2%	2.9%
Total respondents	283	283	283	283	283	283	283

Since PASP is intended to reduce post-harvest losses through the provision of climate resilient PHHS facilities like drying facility and warehouses, the farmers were asked if they had these facilities, if they used them, if the facilities are enough for the quantity of their production and for those who don't use the facility, why. It was found that out of 299 members of the maize and beans cooperatives sampled, 43.1% of them do not currently have drying facilities which means they have to dry using tarpaulins or temporary hangers (see figure 7 below) and 56.9% responded that they do.

Figure 6 Temporary drying facility with maize husks littering the ground after the fruits have been removed in Nyamirama sector used by farmers in Abajeneza and Dufatiyambere Mu Mihigo cooperatives

The hangers are made by cutting down trees which costs about 30000 RwF ($35) on average. Since the structure is temporary, it is used for only one drying period and another one will have to be reconstructed at the next harvest unlike if they had a permanent PHHS structure. Out of the 56.1% that have the drying facility, not all of them use the facility. Some 50.9% of those who have the drying facility do not use it at all; 11.8% of them take only some of their harvest to the drying facility; 23.1% take majority of their harvest and 14.2% take all their harvest to the drying facility. The IFAD Mid Term Review noted that it is preferable for farmers to dry their products in smaller groups to avoid overcrowding the drying facilities with harvests which may result in being unable to dry the products and consequently loss through spoilage. This may be true as it was recorded that many of those who use the drying and storage facilities in the cooperatives where they are available find them not enough for the members and so other members sometimes dry at their homestead.

When those who have the facility but don't use it were asked why they don't, the responses included the distance of the drying facility from their farmlands, the length of time it takes to dry and sell at the cooperative's facility, and the availability of alternative drying means like tarpaulins and temporary tree branches-made hangers. Similar questions were asked to the 299 farmers in maize ad beans cooperatives about storage facilities: this time, 62.2% claimed to have storage facilities and the rest 37.8 do not. Of the 62.2% who have, 46.8% do not use them because of similar reasons stated for the drying facilities.

Figure 7 With the President of Muryawetu and another member of the cooperative on their cooperative's land under construction for the PHHS (drying) infrastructure

It must be said that across the cooperatives in Kayonza District, ten thousand hermetic bags for storage of farm produce have been distributed with each farmer getting an average of three bags according to records obtained from SPIU. Since these bags are air-tight, it protects the content from spoilage and farmers can store their produce meant for household consumption.

	Lack of Milk Handling Skills	Lack of efficient milk handling equipment	Lack of Cooling facilities	Transporting milk over long distance
Not a Problem	36.8%	13.2%	84.2%	15.8%
Moderate	60.5%	7.9%	10.5%	63.2%
Very Serious	2.6%	78.9%	5.3%	21.0%
Total respondents	38	38	38	38

Of the 57 dairy farmers who were sampled, 63.2% of them experienced loss of their milk and the rest 36.8% did not. Among those who lose their milk, it was found that the most serious cause of this loss has to do with milk handling equipment followed by transporting over long distance and milk handling skills. Despite that the preferred container for transporting and holding milk is milk can, only 48.5% of the dairy farmers use the milk cans while the rest use jerricans. This may prompt loss of dairy product since the jerricans cannot be cleaned easily leaving milk from previous use and contaminating their milk. When asked why those who use jerrican do so, they cited different reasons like the heavy weight of the milk cans, the ease of transporting and possibility of traveling with more litres of milk using jerricans, and the higher cost of milk cans compared to the plastic containers.

4.3 Level of Postharvest Management and Technologies Adoption

Majority of the three hundred and fifty-six (356) respondents (99.4%) access climate information. Of these respondents, 82.5% receive climate information daily, 13.9% receive only weekly and the rest 3.6% receive updates on climate monthly. In a multiple response question on the source of the farmers' climate information, we found that majority of the farmers (87.3%) receive climate information on their radio/television among other means; 55.0% receive on their mobile phones; 14.2% obtain the information from neighbours/colleagues; 4.8% receive from extension workers/agronomists and 11.2% receive from community leaders.

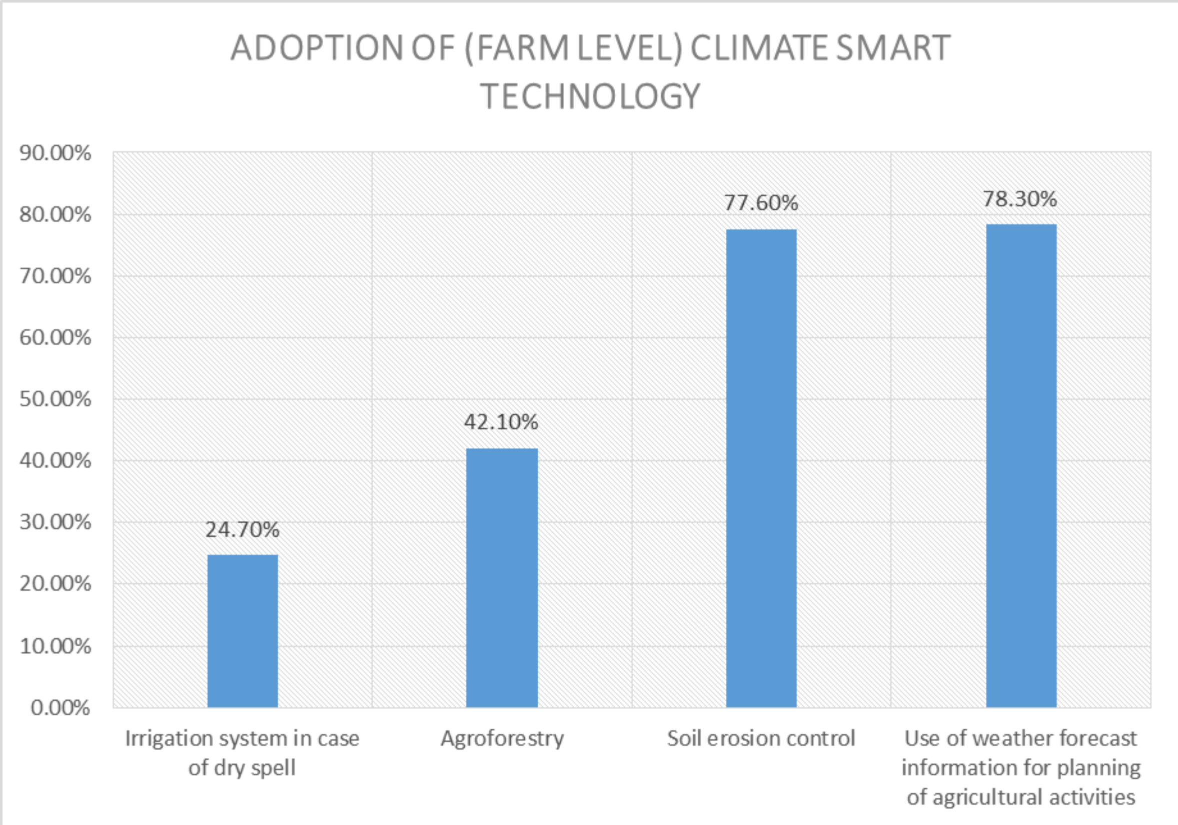

Figure 8: Adoption of Climate Smart Technologies at the Level of the Farm

Farmers were asked to choose from a list of options the technologies they have adopted at the farm level to adapt to climate change: 24.7% of the respondents have adopted the use of irrigation system in case of droughts; 42.1% practise agroforestry; 77.6% use soil erosion control and 78.3% use weather forecast information for planning their agricultural activities (see figure 10 above). Similarly, they were asked to choose the technologies they have adopted at the household level to adapt to climate change: 58.9% of them use hermetically-sealed bags for storage in the house; 50.5% use alternative clean cooking means; 0.6% have adopted forage and silage for their livestock and 22.2% have not adopted any of the listed climate smart technologies (see figure 11 for graphical illustrations). It is clear from figure 10 above that the least adopted climate smart technology, while the percentage is 24.7%, is irrigation system. This is despite that the main stage of crop loss happens on the farm due to crop failure resulting from drought events.

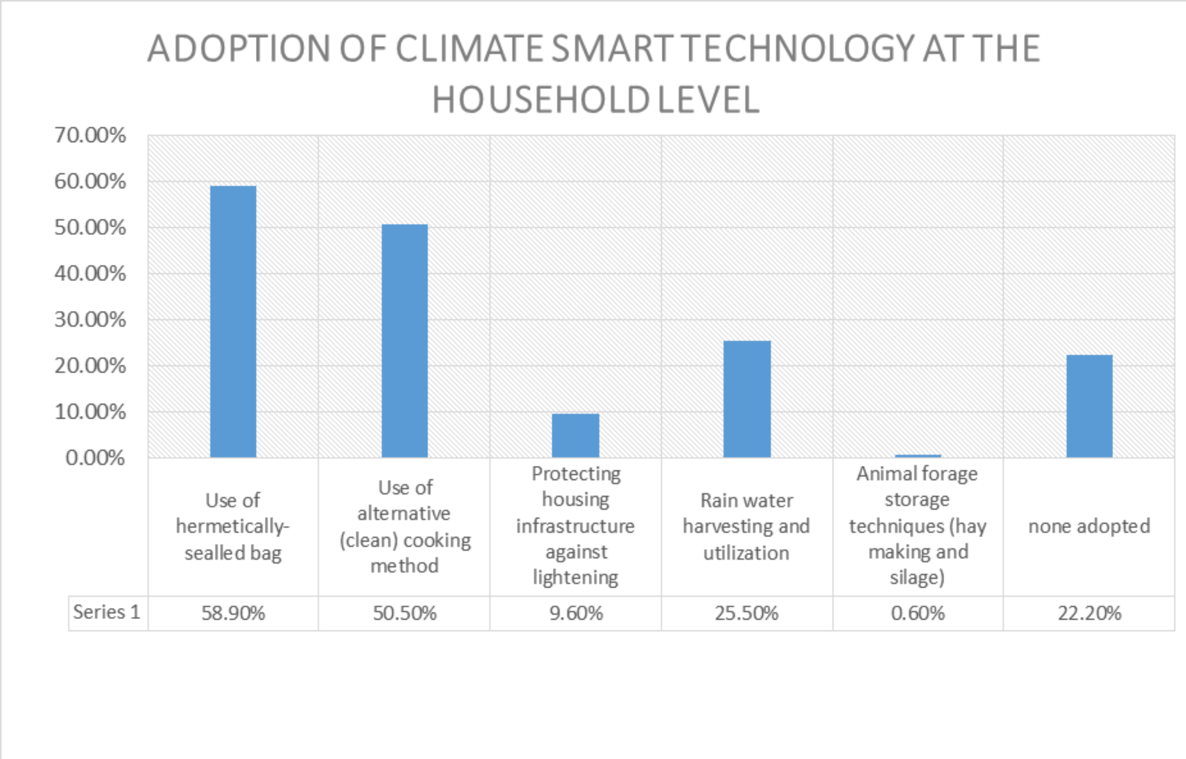

Figure 9 Adoption of Climate Smart Technology at the Household level

4.4 Household food security

Respondents from the crop (maize and beans) and dairy cooperatives were asked how much food they stored in their household for consumption after the last harvest: for maize responses ranged from 0 – 700 kg with an average of 100.0 kg and beans between 0 – 500 kg with an average of 50.0 kg. The milk farmers stored between 1- 8 litres with an average of 3.0 litres. For many of the cooperatives, it was learnt during the focus group discussions, they encourage their members to not sell what is left of their harvest in a season that they experience loss. An example is *Dufatiyambere Mu Mihigo* which experienced serious loss at the last season due to drought event.

	Minimum	Maximum	Median
Quantity of maize stored for household consumption (kg)	0	700	100.0
Quantity of beans stored for household consumption (kg)	0	500	50.0
Quantity of milk stored for household consumption (litres)	1	8	3.0

The leadership of the cooperative encouraged its members to take home what is left of their harvest for consumption and contribute around 6000 RwF (around $7) to facilitate the running of cooperative activities. Also despite that majority of the farmers do not have any other source of income than farming, they engage in different kinds of crop production on both their personal lands and those jointly cultivated on the cooperative's consolidated land. This usually means for the farmers that if one cultivation fails (on personal or consolidated land), they survive on the productivity of the other. As shown in figure 5, whether or not a farmer belongs to the crop cooperative does not mean that they do not cultivate other crops or raise cows or small animals for household consumption.

Table 7 Percentage of food secure and insecure farmers from the 13 cooperatives sampled in Kayonza District

	Frequency	Percentage
Food Secure	178	50.0
Food Insecure without Hunger	58	16.3
Food Insecure with hunger	120	33.7
Total	356	100

Using the USDA methodology for food security, only 50% of the farmers are food secure; 16.3% are food insecure although without hunger and 33.7% are food insecure with hunger. While this figures may differ in a way from what is known of food security in Rwanda (In 2009, the World Food Programme had reported that 21% of Rwandans were food insecure, 22% in 2012 and 19.4% in 2015), they should not be seen as raising force alarms.

Table 8 Adaptive capacity of the farmers

	Yes		**No**	
	Frequency	Percentage	Frequency	Percentage
Have you received training on agricultural practices (such as in crops, livestock, fisheries and forestry) before?	311	87.4%	45	12.6%
Have you received training in any of these non-agricultural enterprises or those related (crafts, services, metal works, trade etc.) before?	69	19.4%	287	80.6%
Have you received training on irrigation practices or natural resources management?	48	14.1%	292	85.9%

This study is being carried out at a time after the most serious drought event in 60 years so a different figure like this is anticipated. It shows perhaps the impact of the drought resulting from climate change on food insecurity. Worrying however is that majority of the farmers engage only in agricultural activities and only few of them have adopted irrigation facilities against flooding despite that their major challenge causing loss is drought. Similarly, when asked the questions in Table 8 above, majority of the famers (80.6%) have not received training in non-agricultural activities and 85.9% of them have not received training on irrigation or natural resource management. Even though PASP may have achieved its aim to a large extent, at least as assessed by respondents (recorded in Table 9 below), it has not really blotted out all the agricultural loss due to climate change. Perhaps this is why out of all the questions asked under the assessment of the project by beneficiaries, only the one on satisfaction on production level is widely rejected.

Table 9 Assessment of PASP by respondents/beneficiaries

	Yes		**No**	
	Frequency	Percentage	Frequency	Percentage
Has adopting or using post-harvest handling technologies increased the quantity of your CIP crop/dairy product?	236	71.5%	94	28.5%
Has adopting or using post-harvest handling technologies increased the quality of your CIP crop/dairy product?	237	71.4%	95	28.6%
Has acquiring knowledge of post-harvest handling and management increased the quantity of your CIP crop/diary product?	308	91.9%	27	8.1%
Has acquiring knowledge of post-harvest handling and management increased the quality of your CIP crop/diary product?	308	91.9%	27	8.1%
Are you satisfied with the quantity of CIP crop/ dairy product that you sell compared to what you expected?	103	30.8%	231	69.2%
Have your customers complained about the quality of your CIP crops/dairy since using the post-harvest handling technologies	80	24.1%	252	75.9%

CHAPTER FIVE

SUMMARY, CONCLUSION AND RECOMMENDATION

The results have shown that climate change truly impacts agricultural production and productivity particularly through long-term and very severe droughts in Kayonza district. PASP has done well in providing trainings to farmers and supporting them with PHHS infrastructure. Farmers have adopted many postharvest technologies like rain water harvesting, clean cooking, drying and storage infrastructures, hermetic bags etc. But even though PASP may have achieved its aim to a large extent cutting postharvest losses as confirmed by the beneficiaries that we assessed, there is still a lot more to do. We understand that PASP's focus is on addressing climate-induced losses at postharvest level, but climate change, from our results, affects agriculture both on the field and at post-harvest level. While crop losses are recorded at both stages, loss on the farm is more than the loss recorded during post-harvest handling. It is therefore smart to plan for climate change at both farm and off-farm levels in order to win big addressing economic losses and food insecurity. The food security figures reported here may be high, but it is not to say that PASP has not achieved any win. The high figure, as has been noted, may be due to the serious drought event witnessed in the previous agricultural seasons.

As PASP concludes in less than a year, it is expected that majority of the cooperatives would have built their drying facilities now and have a standard place to dry, but some are still in the process of building the structures or raising funds to do so. While IFAD may have advised that farmers dry in smaller unit, it is reported by some cooperatives that when farmers dry at their homes, it is usually a problem to get the produces aggregated again for sale at the level of the cooperatives. Weight, capacity and high cost of milk cans and bad roads have been suggested as the reason for not using the recommended milk cans by some of the farmers. Getting lighter weight milk cans for farmers at low price may increase the use of the cans and hence reduce losses Reducing the distance travelled by dairy farmers by using Milk Collection Point which are closer to the farmers is advised. Also, there is need to increase the adaptive capacities of smallholders beyond crop or livestock farming alone. Farmers need to be engaged in off-farm activities in addition to their farming as other sources of income. Development and adoption of drought resistant varieties of crops should be encouraged and farmers should be trained on irrigation farming to adapt to drought events.

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APPENDICES

APENDIX 1

Questionnaire

UNIVERSITY OF IBADAN
CENTRE FOR SUSTAINABLE DEVELOPMENT
IBADAN, NIGERIA

Questionnaire no: ______ Long.: ________ Lat.: ________ Alt.: ________ Date: ___________

Dear respondent,

The questions below are intended to assess the Climate Resilient Post-harvest Agribusiness Support Programme (PASP) in Kayonza District, Eastern Rwanda. The questionnaire is designed to elicit information from selected PASP beneficiaries for research purpose. Rest assured that information obtained through these set of questions will be treated with utmost confidentiality. We look forward to your cooperation.

SECTION A: SOCIODEMOGRAPHIC CHARACTERISTICS

S/No	Questions/Statement	Response	Coding
	Please indicate your sector (e.g. Murundi, Gahini etc)	………………….	
	What is the name of the cooperative you belong to?	………………………….	
	Please indicate your gender	Male ☐ Female ☐	0 1
	Please indicate your marital status	Single ☐ Married ☐ Widowed ☐ Divorced ☐ Other (specify).....................	0 1 2 3 4
	Please indicate your age range	15-30 years ☐ 30-45 years ☐ 45-60 years ☐ More than 60 years ☐	0 1 2 3
	Please indicate your level of education	No formal education ☐ Primary Education ☐ Junior High School ☐ Higher School ☐ University ☐	0 1 2 3 4
	Total number of members of household (including you)	....	
	What is the total size of farmland you cultivate on?	Less than 0.5 ha ☐ Between 0.5-1.0 ha ☐ Between 1.0-2.0 ha ☐ More than 2.0 ha ☐	0 1 2 3

	Which of these are you involved? (multiple choices allowed)	Maize ☐ Beans ☐ Cow ☐ small domestic animals ☐ Other crops ☐	0 1 2 3 4
	Do you engage in any other economic activity other than farming?	No ☐ Yes ☐	0 1

SECTION B: POST-HARVEST LOSSES

S/No	Questions/Statement	Response	Coding
CIP Crops (fill this section if you engage in CIP cultivation otherwise move to the diary section			
1	What quantity of maize and beans did you produce at the last harvest?		
	Maize	………..kg	
	Beans	………..kg	
2	Did you experience loss of your produce?	No Yes	0 1
If yes to question 2, answer questions 3-5 otherwise proceed to 6			
3	Please estimate how much of your produce that is lost.		
	Maize	………..… kg	
	Beans	………..… kg	
4	At what stage do you experience the loss most? *Choose 1. On the field; 2. Harvesting or handling (drying, winnowing and storage); 3. Processing; 4. Transport and Marketing*		
	Maize		
	Beans		
For question 5, write (1) if it's a very serious, (2) if it is a moderate and (3) if it is not a problem at all			
5	What are the causes of your product losses? (multiple responses allowed)	Drought through frequent dry spells (…..) Damage by pests & diseases at farm and PHHS stage (….) Strong winds affecting both farms and PHHS infrastructures (…..) No adequate PHHS equipment/infrastructure Flooding of farms (….) No adequate transport (…..) Lack of market access (…..) Others (specify)................................. (…..)	
6	Do you have a drying facility in your area?	Yes ☐ No ☐	0 1
7	If yes to 8, do you use the facility to dry your crops?	No ☐ Some of the harvest is taken there ☐ ☐	0 1

		Majority of the harvest taken there All harvest is taken there ☐	2 3
8	If you use the facility, is it enough to dry the crops of all members of your cooperatives?	Yes ☐ No ☐	
9	If you do not use the drying facility, why?	It is too far from where I stay ☐ the drying facility is too small ☐ it takes too long to dry there ☐ I use another method of drying ☐ No particular reason ☐ Other …………………………	0 1 2 3
10	Do you have a storage facility in your area?	No ☐ Yes ☐	0 1
11	If yes to (10), do you use the facility to store your crops?	No ☐ Some of the harvest is taken there ☐ Majority of the harvest taken there ☐ All harvest is taken there ☐	0 1 2 3
12	If you use the storage facility, is it enough to store the crops of all members of your cooperatives?	Yes ☐ No ☐	
13	If you do not use the storage facility, why?	It is too far from where I stay ☐ the storage facility is too small ☐ I have another method of storage ☐ No particular reason ☐ Other …………………………	0 1 2 3
14	How do you sell your products (multiple choices allowed)?	I sell to neighbours ☐ I sell in the local market ☐ I sell to traders ☐ I sell at my cooperative ☐ Others (specify) ……………………………	
15	How does your product get transported (from farm to drying/storage/market)?	On my head ☐ On bicycle ☐ On motorcycle ☐ On truck ☐ I don't transport my product ☐	
16	What are the existing on-farm climate smart technologies/best practices that you have adopted?	Use of hermetic bags for drying ☐ Irrigation system in case of dry spell ☐ Agroforestry ☐ Soil erosion control (e.g. terraces) ☐ Use of weather forecast information for planning of agricultural activities ☐ Other (please specify)………………………..	
Cattle (fill this section only if you have cow(s))			
17	How many cows do you have?	……………	
18	What quantity of milk do you		

	produce per day?	……………litres/day	
19	Where do you sell your milk?	To my neighbours ☐ At milk collection centres ☐ To ambulant dealers ☐ To processing unit ☐ I do not sell the milk ☐	
20	Have you experienced any qualitative loss of your milk before?	Yes ☐ No ☐	0 1
21	If yes, how much per day do you lose?	……..litres	
22	What are the causes of your milk loss? (Choose (1) if it's a serious problem, (2) if it is moderate and (3) if it is not a problem at all)	Lack of milk handling skills (….) Lack of efficient milk handling equipment (...) Lack of cooling facilities (….) Long distance in transporting (….) Other …………………………. (….)	0 1 2 3
23	Do you have milk collection centres (MCC) in your area?	Yes ☐ No ☐	
24	If yes, do you take your milk there?	No ☐ I take some of my milk there ☐ I take a big part but not all ☐ I take all my milk to the MCC ☐	
25	If you do not take your milk there, why? (multiple responses allowed)	The place is far ☐ They reject my milk ☐ I do not have the equipment to transport ☐ I can store/handle my milk effectively ☐ I do not have so much milk to take there ☐ Other ………………………………	
26	Where do you put your milk while transporting it?	Milk cans ☐ Jericans ☐ Plastic buckets ☐	
27	If you use plastic bucket or jerican, why?	…………………………………	

SECTION C: POST HARVEST MANAGEMENT

S/No	Questions/Statement	Response	Coding
Respond to 1 and 2 if you are involved in maize and beans otherwise proceed to 3			
1	Please specify which of the following applies to the drying facilities in your area	Proper water drainage system ☐ Rain water harvesting facilities ☐ Durable construction materials ☐ Access to clean energy ☐ Others (please specify) ………………………	0 1 2 3
2	Please specify which of the following applies to the storage facilities in your	Proper water drainage system ☐ Rain water harvesting facilities ☐	0 1

	area	Durable construction materials ☐ Proper ventilation system ☐ Access to clean energy ☐ Others (please specify) ……………………….	2 3 4
3	Do you access climate/weather related information?	Yes ☐ No ☐	0 1
4	If yes, indicate through which main media/channels	Radio/ Television ☐ Mobile phone ☐ Neighbours or colleague ☐ Agronomists/Extension workers ☐ Community leaders ☐ Others ☐	
5	How often do you receive the information?	Daily ☐ Weekly ☐ Month ☐	
6	Pick one or more of the following climate resilient technologies that you have adopted.	Use of alternative (clean) cooking ☐ Protecting housing infrastructure against lightening ☐ Rain water harvesting and utilization ☐ Household wastewater management ☐ Hermetic bags for storage ☐ Animal forage (hay &silage) ☐ None adopted ☐	
7	Has adopting or using post-harvest handling technologies increased the quantity of your CIP crop/dairy product?	Yes ☐ No ☐	0 1
8	Has adopting or using post-harvest handling technologies increased the quality of your CIP crop/ dairy product?	Yes ☐ No ☐	0 1
9	Has acquiring knowledge in post-harvest handling and management increased the quantity of your CIP crop/ dairy product?	Yes ☐ No ☐	0 1
10	Has acquiring knowledge in post-harvest handling and management increased the quality of your CIP crop/ dairy product?	Yes ☐ No ☐	
11	Are you satisfied with the quantity of CIP crop/ dairy product sold compared to what you have expected?	Yes ☐ No ☐	0 1
12	Have your customers complained about the quality of your CIP crops/dairy since using the post-harvest handling technologies	Yes ☐ No ☐	0 1

SECTION D: FOOD SECURITY AT THE HOUSEHOLD LEVEL

S/No	Questions/Statement	Response	Coding
1	Has the PASP project influenced how much food you keep for household consumption?	Yes ☐ No ☐	
2	What quantity did you store for your household use?		
	Maize	…………(kg)	
	Beans	………….(kg)	
	Milk	………..(litres)	
3	"In the past twelve months, we worried that our food would finish before we got more or food to buy more." This happened	Often ☐ Sometimes ☐ Never true ☐	
4	"In the past twelve months, we couldn't afford to eat balanced diet." This happened	Often ☐ Sometimes ☐ Never true ☐	
5	In the last 12 months, did you or other adults in the household ever cut the size of your meals or skip meals because there wasn't enough food?	Yes No	1 0
6	(If yes to Question 4 above) How often did this happen?	Often Sometimes	1 0
7	In the last 12 months, did anyone in your household ever eat less than they should because there wasn't enough food or money for food?	Yes No	1 0
8	In the last 12 months, was anyone from your household ever hungry, but didn't eat, because you couldn't afford enough food?	Yes No	1 0
9	In the last 12 months, did you or anyone from your household lose weight because you didn't have enough food or money for food?	Yes No	1 0
10	In the last 12 months did you or other adults in your household ever not eat for a whole day because there wasn't enough money for food?	Yes No	1 0
11	(If yes to Question 9) How often did this happen?	Often Sometimes	1 0
Note: Questions 12-19 are asked if the respondent has children in the age range 0-18years.			
12	"In the last 12 months, we relied on only a few kinds of low-cost food to feed our children because we were running out of food or money to buy food."	Often Sometimes Never true	2 1 0
13	"In the last 12 months, we couldn't feed our children a balanced meal because we couldn't afford that."	Often Sometimes Never true	2 1 0
14	"In the last 12 months, the children were not eating enough because we just couldn't afford enough food."	Often Sometimes Never true	2 1 0
15	In the last 12 months, did you ever cut the size of any of the children's meals because there wasn't enough money for	Yes No	1 0

	food?		
16	In the last 12 months, were the children ever hungry but you just couldn't afford more food?	Yes No	1 0
17	In the last 12 months, did any of the children ever skip a meal because there wasn't enough money for food?	Yes No	1 0
18	(If yes to Question 16) How often did this happen?	Often Sometimes	1 0
19	In the last 12 months, did any of the children ever not eat for a whole day because there wasn't enough money for food?	Yes No	1 0

SECTION E: HOSEHOLD ADAPTIVE CAPACITY

1	Please indicate your number of years of education	………...years
2	Total number of member(s) of household not working	…………
3	Have you received training on agricultural practices (such as in crops, livestock, fisheries and forestry) before?	No ☐ Yes ☐
4	Have you received training in any of these non-agricultural enterprises or those related (crafts, services, metal works, trade etc.) before?	No ☐ Yes ☐
5	Have you received training on irrigation practices or natural resources management?	No ☐ Yes ☐

APPENDIX 2

Work Plan

The following is the proposed plan of activities for the three-month field practicum.

Table 10 Gantt chart showing work plan for the three month field practicum

S/No	Activities	March				April				May			
		Week											
		1	2	3	4	5	6	7	8	9	10	11	12
1.	Preparation and travel plan to field trip	X											
2.	Familiarity with the project team members	X	X										
3.	Work with the project design plan and visit to some field site		X	X	X	X							
4.	Data Collection			X	X	X	X	X	X	X	X		
5.	Monthly Report				X				X				X
6.	Computation and analysis of data and compilation of reports									X	X	X	
8.	Submission of report												X
9.	Predation and travel plan from project site												X

APPENDIX 3

Pictures

Figure 10 With farmers at their drying facility in Twitezimbere Nya cooperative in Gahini sector

Figure 11 A dairy farmer arriving at the GAFCO Milk Collection Centre in Gahini on his bike with Jerri cans containing milk

Figure 12 Discussing with one of the beneficiaries in Gahini with the help of the PASP district contact person

Figure 13 With members of Dufatiyambere cooperatives on their consolidated farmland